This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

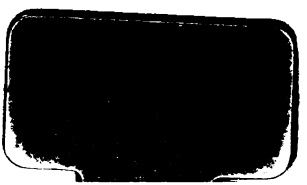
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

SCIENCE SIMPLIFIED.

FIRST SERIES.

2/-



SCIENCE SIMPLIFIED,

AND

PHILOSOPHY,

NATURAL AND EXPERIMENTAL,

MADE EASY.

BY THE REV. DAVID WILLIAMS, M.A.,

Author of the "Preceptor's Assistant,"
"Composition, Literary and Rhetorical, Simplified," &c., &c.

FIRST SERIES,

CONTAINING

I.—ANIMAL PHYSIOLOGY,
II.—VEGETABLE PHYSIOLOGY,
III.—MECHANICS,
IV.—OPTICS,
V.—ASTRONOMY,
VI.—GEOLOGY.

LONDON:
W. & T. PIPER, 23, PATERNOSTER-ROW.

1851.

148. c. 42.

MARCHANT SINGER AND CO., PRINTERS, INGRAM-COURT,
FENCHURCH-STREET.

ADDRESS

TO

PARENTS, GUARDIANS, & TEACHERS.

It is hoped the work now offered to the attention of parents, guardians, and teachers will be found to contain a fund of useful and practical knowledge—a storehouse of facts and information in the various branches of science and philosophy—adapted not only to instruct but to interest and lead the youthful mind to think and inquire, to compare and investigate; in a word, to qualify the learner for the contemplation and discovery of truth, and to embue his mind with the points of real and useful knowledge—the leading principles and great axiomatic truths of science and philosophy. The plan adopted is calculated to collect and concentrate into a focus that knowledge and information which, in the usual method of treating scientific subjects, is spread and scattered over a wide and an expansive surface; or, to adopt an emphatic and a familiar expression, it condenses into a nut-shell that which is diffused through a mass of countless and cumbersome volumes, affording the maximum of information in the minimum of space, and, while plain to the mind, will be found brief for the memory.

Among its other advantages over the old method of verbiage and profuse dissertation—of book-plodding and book-poring—it will not only smooth and enliven, shorten and facilitate the approach to the temple of science and the fountain of philosophy, but it is pecu-

liarly and emphatically adapted to bring down the arcana or mysteries of science and philosophy to the simplest and the tenderest capacity. In a word, by its medium the solution and comprehension of scientific and philosophical knowledge may be converted into a rational amusement and an instructive recreation, into an amicable contest and rivalry of literary and scientific skill and improvement between parent and child when families are assembled round the domestic hearth, instead of occasioning learning and science to be viewed as a dull and a repulsive—a dry and an uninteresting study. The plan, it is true, is not novel or of recent invention; the "*Compendium Physico Aristolico Cartesianæ*" of Sincerus—a work of considerable merit for the age, and from which subsequent compilers have borrowed much without acknowledgment,—was published at Amsterdam about the end of the sixteenth century of the Christian era. Above thirty years ago the author of "Science Simplified" introduced the plan into one of his educational works; but since the appearance of his little work a host of similar books have been published, in which his matter has been so artistically diluted, and arranged in a form and finery so fantastic, that it is with some difficulty the descent of the bantlings can be traced to their progenitor.

A few more introductory words seem necessary.

It has long been the complaint of all thinking and observant persons that our present mode of school education is erroneous and defective, on account of the absence of *scientific instruction* in schools or seminaries, and the attention of learners being confined to, and the time allotted for their school education being consumed in, the *acquirement* of *mere words*,* or, in the language of the poet, of

"A *little* Latin and a *smatch* of Greek,"

with, as one of the most sagacious and enlightened

* No axiomatic truth has been more recognized and more acknowledged by the intelligent and thinking class of the com-

writers on educational subjects says, "a few odds and ends of bald French phrases, and the rules and tables of some elementary compilation on arithmetic. Nor is *female education less defective, less irrational, less inefficient.* A smattering of French and Italian—dancing, singing, piano playing—a something about the globes and geography—and a parroting, and that, too, of the most trifling nature, of *the ologies* and *the onomies*, *the isms* and *the asms*, *the istics* and *the astics*, are considered the very perfection and consummation of female intellectual attainments." And these schemes—schemes that almost justify the poet's invective, that accomplishments and a heap of incongruous shreds and scraps and patches

munity than that the mode of education in current use is not only defective and inefficient, but in many of its effects and consequences highly mischievous and inimical to the best interests of society; and the causes are obvious. 1st, *The incompetency, aye, the absolute inadequacy of the generality of those who assume the office of instructors;* and, 2nd, *their inability and unwillingness to select fit and proper educational works*—works calculated to awaken and elicit the powers of the youthful mind and enable it to investigate, to compare, and to reason. The case is very different with the most enlightened nations of Europe, particularly France, Prussia, and Germany; and the consequence is, that the generality of the natives of those countries are more intelligent, and speak their languages much more correctly, than is the case with the generality of the natives of England, Scotland, and Ireland. In those countries teachers are in general intelligent and well educated, and the educational works, instead of being filled with meagre and trite information and couched in vicious and slovenly language, are well written and stored with useful knowledge. On the contrary, in our notable schemes of education, the propriety and obligation of imparting to the youthful mind habits of inquiry and investigation, of thought and reflection, seem never to have entered into the conception of their broachers; and the error—an error fundamentally and emphatically calculated to incapacitate the mind for the contemplation and discovery of truth—is faithfully and tenaciously observed by the supporters and upholders of those schemes. No rational and thinking person can therefore be surprised at the result, that in the greater part of our population the powers of the mind are allowed to become waste and unproductive.

of learned litter and lumber "have taken Virtue's place" and "Science's usefulness,"—are called, and *strangely believed* to be, EDUCATION,—are mistakingly and mischievously considered *to be the proper training and the legitimate institute* of immortal minds—of minds that are to work out their purification for the enjoyment of a higher and a more perfect state of existence by the due and rational exercise of the heavenly endowment of intellect. In both cases, as well for males as females, the concoctors of the schemes seem to have strangely lost sight of the wise and weighty maxim propounded by the highest authority, "It is better to speak five words with understanding than ten thousand in an unknown tongue." Never on any occasion or for any purpose was a master mind, who will free the understanding of mankind from the trammels of error and superstitious prejudices—more required, than *for the rectification and rationalizing our educational notions and practices*. To further the accomplishment of this great and hallowed purpose should be the earnest and unwearied endeavour of every person, both male and female, to whom God and Nature have given a sound understanding and a humane heart. "When *the elements and principles of scientific knowledge*," adds the same philanthropic monitor to whom I have just alluded, "constitute part of educational topics, *we shall not have our children, after drawling away their allotted penance of school education, returned on our hands with starved and impaired intellects*, possessing little or nothing of that knowledge which is useful and necessary in the affairs of life, and of that information which is essential for stamping on them the impress and character of intelligent beings and useful members of society; in a word, for enabling them when they appear on the grand theatre of life to discharge well and wisely their respective vocations of usefulness and duty." To further this great and desirable purpose, the author of "Science Simplified," &c. hopes that he has

presented to teachers of youth of both sexes a manual containing a fund of invaluable knowledge, unequalled for variety and extent, and condensed into the smallest possible compass that can be devised, and that, too, at a moderate cost; that he has verified the truth and application of the sententious and emphatic apothegm—multum in parvo—a store-house in a nut-shell; and that his little volume will be found to contain the most interesting and instructive portions of numerous and expensive tomes; but in making this declaration, he deems it a duty due to himself to say, though the problems, propositions, or questions have been suggested by the valuable statements and observations to be found in those works, the solutions or answers are generally attributable to himself: in many cases the problems have been suggested from his own observations of the appearances, phenomena, and occurrences of nature, and the results and operations of art.

An additional word addressed to the most interesting and influential portion of the social fabric—MOTHERS, both those who are in the exercise of the great and high prerogative, as well as those who are desirous of the same distinction and destiny.

As Mothers are the most influential of teachers, and as it is the office of WOMAN by Nature to impart the elements of thought, to prompt the earliest speech, and to awaken the latent powers of the infantine mind, it is of the highest importance that, when the tablet of the heart is fairest and the mind most easily shaped and influenced, the teacher should be duly qualified for the task—a task of the greatest and most vital nature in this our sublunary state of existence. To enable mothers to perform that duty with facility and effect, some knowledge of the causes of the appearances and operations of Nature—of the products, mysteries, and results of art—the leading and important events of history—some elementary notions of the principles of mechanical science and of

natural philosophy, in addition to the sublime truths and the humanizing doctrines and precepts of religion and moral philosophy, is necessary and desirable for the purpose of instilling into the young mind the rudiments of science, and gratifying the inquisitiveness of children respecting the reason and nature of things and appearances, as well as of storing their minds with those principles that are to be their guidance and direction in future life, by imparting to them the due and proper tone and bias which moral rectitude, sound learning, and true religion impart. This great and hallowed purpose—this first and most indispensable of duties—the author of "SCIENCE SIMPLIFIED" hopes he will have enabled his countrywomen, and teachers—more especially the judicious, the intelligent, and the conscientious portion of that important section of society—to put into execution by the publication of that little book, in addition to THE FINISHING PRECEPTOR AND PRECEPTRESS, a work he has in a state of forwardness.

SCIENCE SIMPLIFIED,

AND

Philosophy made easy.

ANIMAL PHYSIOLOGY.

ANIMAL PHYSIOLOGY is the science which explains the structure and organization, external and internal, of the animal machine, its functions, nutrition, growth, decay, and reproduction.

The animal system, in its most complicated and perfect example,—Man, as well as in the whole brute creation, from the mammoth to the mite, consists, like the solar system, of a series of subordinate systems or actions, all concurring to one great end—*life*,—for which they are all adapted with consummate perfection and the most harmonious construction. In its structure all the mechanical powers are inherent; and though that structure is exquisitely tender and delicate, it is adapted for the exertion of the greatest force and power—for the endurance of fatigue and the accomplishment of the greatest and most difficult achievements; and what still further excites and increases wonder is, that by Nature's self-adjusting processes—a property in which man's or artificial mechanics are wholly and absolutely impotent—it possesses the power and faculty of self-reparation and self-renovation:

in a word, as the most eloquent of human tongues has said in the truest spirit of philosophy and the most exalted strain of pious reflection, "it affords the finest and the most demonstrable proofs of a Divine Providence;" and, it may be added, is admirably adapted to lead the mind to just and elevated notions of the consummate power, wisdom, and beneficence of Him—"Nature's controller, author, guide, and end"—who called the human race and all created matter into existence.

In what does life or the vital principle consist?—In the mutual and sympathetic action and reaction of all the important functions (the respiration, digestion, absorption, circulation, and secretion) of the various organs comprising the animal machine, viz., the brain, the heart, the lungs, &c. That the vital principle—or, to adopt the beautifully paraphrastic language of Scripture, the vivifying element by which "we live, and move, and have our being,"—consists in the assemblage, the harmonious action and reaction, and the bond of union of those organs, is unquestionable, although cases are recorded in medical annals, in which the brain has been seriously disorganised without affecting the vital principle; the heart has been wounded without causing death; and persons have lived for many years, though subject to extensive structural disease of the lungs.

Why do organic or living bodies perish; or what occasions death?—The stiffening of the muscles of the human frame, the obliterating of its vessels, and the lessening of the sensibility of the nerves. The leading cause of the physical phenomenon of old age is the obliteration and obstruction of the smaller bloodvessels, by which the blood is prevented from reaching all parts of the body to supply them with nutriment.

WHY are the state of health, the progress of disease, and the approach of death, indicated by the slowness or quickness, the strength or feebleness, of the pulse?—BECAUSE, as the heart when in a state of health contracts slowly and fully on its contents, a due quantity of blood is propelled at every beat into the arterial tubes, and the pulse is therefore slow and regular; but when under the disturbance of disease,—as it contracts feebly, being then unable to propel from its cavity the usual quantity of blood,—it is obliged more frequently to contract on its contents, and its action consequently becomes accelerated and irregular. Hence the pulse at the wrist is quick and intermittent; and as the action of the heart becomes more and more diminished, the pulse flutters beneath the finger irregularly and feebly, and at last ceases altogether.

WHY do joy, grief, and anger, when unexpectedly and vehemently aroused, occasion death?—BECAUSE the sympathetic action and relation which subsist between those organs that constitute the phenomenon LIFE, or the vital principle, are overwhelmed by their intense power. Sudden shocks, blows, stunning, and poison, occasion death in a similar manner, namely, by the instantaneous suspension of the action and relation of the brain, heart, and lungs.

WHY, in the act of dying, do some persons preserve their intellectual faculties to the last, while delirium takes place in the case of others before dissolution?—BECAUSE those phenomena depend on the order in which the vital organs cease or relinquish the performance of their functions. Thus—when death is induced by any disease primarily commencing in the brain—the heart, arteries, liver, and lungs will continue to perform their functions, though the patient may be in a profound state of stupor or insensibility; but when the heart,

lungs, or liver are primarily affected, the brain, the organs of sense, and the intellectual faculties preserve their energies to the latest moment of existence.

WHY does the body seem, in some cases, to die from the centre to the extremities, while, in others, it dies from the extremities to the centre?—BECAUSE, in the first mentioned cases, the vital organs are the first affected; whereas, in the second, the extremities are the first affected. The first mentioned class of death is produced by sudden shocks and vehement passions of the mind, or by poisons, which occasion the instantaneous suspension of the action of the brain, heart, lungs, &c., when the body dies from the centre to the circumference, the surface of the body remaining warm, while the central organs have ceased to perform their functions; but the second class of deaths is produced generally by diseases, which gradually exhausting the vital powers, the body dies from the extremities to the centre, when the surface of the body becomes cold, while the central organs are still exerting their dying energies to support the vitality of the system. The suddenness or the prolongation of death depends on the circumstances, whether the vital organs simultaneously or consecutively cease to perform their functions.

How does concussion of the brain occasion death?—THE sympathetic action and relation which subsist between the brain and the heart being interrupted by the effects of the blow, the action of the heart is thereby immediately depressed.

How does apoplexy occasion death?—BY the balance of the circulation of the blood being interrupted either by the heart being thrown into extraordinary action, so that a larger volume of blood than usual is thrown upon the brain, or by

the ossification of the valves of the heart, by which event the circulation of the blood is interrupted.

How are the phenomena of the nervous affections produced?—By the disorganization or lesion of the brain, the spinal chord, or the nerves.

What occasions the oppression of the chest called the incubus or night-mare?—The pressure of the heart, while pulsating, on the lungs, an affection occasioned by the sleeper lying on his back.

What occasions the annoying feeling called the heart-burn?—The conversion of the food, particularly vegetable food, into a species of acid in the stomach.

What occasions the distortions of epilepsy?—When the patient attempts to put his limbs or the muscles of the face into action, various sets of other muscles than those designed by nature for the operation act from the disorganized state of his body, and thus a contrary effect is produced to that which the patient intended.

How are nævi maternæ, or birth-marks or mother-spots, produced?—They are produced by a relaxation and weakness of the bloodvessels, which also become augmented to an unusual number.

Why are some persons subject to the ravages of contagious disease, while others living in the same house or locality are exempt from its attack?—Because they are labouring under aptitude and susceptibility of temperament adapted to its receptivity and propagation.

Why is death occasioned by hanging, drowning, smothering, or strangling?—By the suspension of respiration, for the air not being admitted into the lungs or respirating apparatus, the blood is not arterialized, but is sent to the brain in its venous state, and therefore acts as a poison, and paralyses the functions

of that organ. In hanging, death is not always produced, as is generally supposed, by dislocation of the bones of the neck, but by the cause just stated, and it is on this account that a tube introduced into the windpipe just below the cord which suspends the body will preserve life.

How is disease occasioned?—ALL circumstances that tend to debilitate the system generally, whether occasioned by atmospheric vicissitudes, by residence in an unhealthy locality, by unwholesome and insufficient food, by the abuse of spirituous liquors, or by debauchery, are predisposing causes of disease.

How is pestilential infection, or infectious agency, occasioned?—EITHER by the miasmic particles arising from the decomposition and putrefaction of animal or vegetable substances, stagnant water, cesspools, &c. or by the morbid effluvia which are thrown off from the body in certain disorders, such as small-pox, measles, consumption, yellow and scarlet fever, puerperal peritonitis, Turkish and Egyptian plague, &c. The emanations emitted by the persons so affected, if received into the lungs of others, impregnate the blood with the virus and produce in them a like disease.

WHY is the health injured when the temperature of the body is reduced, by cold or other cause, below its natural standard?—BECAUSE the blood, being driven away by the cold, chill, &c., from the external surface of the body, the balance of the circulation is destroyed, when its whole mass is thrown upon the internal organs, which are oppressed by the increased load, and become consequently deranged.

WHY does sleeping in damp beds, or getting wet feet or clothes, in the first case occasion danger, and in the second give "cold?"—BECAUSE the heat is abstracted from the surface of

the body by the damp or moisture, when the same result succeeds as stated in the preceding solution. The reason that persons at sea, though drenched with sea-water, and that persons bathing or washing themselves in salt and water do not "catch cold" is, that the salt of the water retards evaporation; besides, acting as a stimulant, it promotes the due circulation of the blood.

WHAT were the predisposing causes of the dancing mania which prevailed among the peasantry of Germany during the fourteenth century?—NERVOUS weakness, arising either from great physical sufferings or the long-continued operations of superstition. Diseases of this nature are propagated among a community by morbid sympathy. The tarantism, or disease occasioned by the bite of the tarantula, or Italian spider, which spread over Italy in the fifteenth century,—the convulsions and spasmodic gesticulations which prevailed in the Shetland islands, at Berlin, Paris, among the Jumpers in Cornwall, and the disciples of Whitfield in Britain and America,—and the leaping ague prevalent in Forfarshire in the seventeenth century, originated in the same manner.

WHAT occasioned the pestilence called the "Black Death," which raged during the fourteenth century throughout the world?—SOME species of atmospheric derangement operating on constitutions reduced by physical privations and mental excitement. Like the cholera morbus of the present century, it broke out in the east (China), and extended to the west.

WHAT occasions sea-sickness? — THE oscillations of the vessel and the appearance of its motion and of the surrounding things and objects.

How may sea-sickness be in some degree prevented?—BY keeping the eyes shut, so as to prevent the vision of the

vessel's motion and the swinging backwards and forwards of its contents. While on deck, looking straightforwards to the horizon will sometimes prevent the same affection.

WHAT occasions the diseases which prevail on the sea-coasts near the tropics?—THE miasmata (*i. e.* exhalations of the putrefying bodies) arising from the putrefaction of the sea-water after a long continuance of calm weather.

How is animal motion produced?—THE act of volition produced by the influence of the brain being transmitted from that organ downwards along the diverging fibres which communicate between it, the spinal chord, and the nerves leading from it to the muscles of the member wished to be moved, an influence is produced excitant of the property of contractility inherent in the muscular fasciculi or bundles, by which they are contracted.

How is the sensation of vision produced?—BY the influence of the impression produced by the rays of light on the expanded filaments of the optic nerve being conveyed by the trunk of the optic nerve to the brain.

*** The *modus operandi* (*i. e.* the operating process or effect) of sensation produced on any other of the organs of the body is produced in a similar manner to that of vision.

WHAT occasions blindness or the inability of recognising the presence of objects?—THE want of power of the nerves to convey the impression of the pictures or images of objects on the retina to the brain: an inability occasioned by injury produced to the nerve.

WHY have animal bodies bones?—BECAUSE they give strength and firmness to the frame.

WHY are bones hollow?—BECAUSE hollow cylinders are much stronger than solid ones of equal length and weight.

WHY are bones more or less of a cylindrical shape?—BECAUSE they present a greater facility and power of motion in those parts subject to motion.

WHY is flesh a necessary part of the human body?—BECAUSE it gives firmness and connection to the bones.

WHY are the flesh and the bones covered with skin?—BECAUSE it preserves them from decay and injury, and gives beauty to the form.

WHY is fat of use to organic bodies?—BECAUSE when the supply of carbon fails from any defect of the blood, the fat supplies the deficiency, by the absorbent vessels taking it up from its various receptacles and conveying it to the veins, which transmit it to the lungs, for the generation of carbonic acid gas, and the consequent evolution or production of animal heat.

WHAT occasions the body to be fat or lean?—FATNESS, or obesity, is occasioned by many causes, such as luxurious living, want of exercise, excessive sleep, corporeal or mental inactivity, &c. On the other hand, spare living, insufficiency of rest or sleep, irritability or fretfulness of disposition, mental anxiety, or activity of mind, occasions leanness. Leanness is also produced by organic diseases occasioned from the air-cells of the lungs being choked up with tuberculous matter. Intense or continued heat, whether natural or artificial, will also tend to diminish fat; a process resorted to for suddenly reducing the weight of jockeys by immersing them in hot dung.

How is the vital process of animal heat generated, and what is the *rationale* (*i.e.* the detail of the reasons) of its production?—BY respiration; for the air in breathing loses its oxygenetic property, and is replaced by an equal quantity

of carbonic acid gas, which is ejected from the lungs at a temperature of above 90° Fahrenheit.

How is carbonic acid gas produced in animal bodies?—By the union of the carbon of the blood with the oxygen of the air.

How is that union occasioned?—As the chyle contains a large portion of carbon, that carbon is carried in the same channel as the blood to the lungs, where it is consumed by the action of the oxygen of the air, in the production of carbonic acid gas for the evolution of animal heat.

What occasions the difference of cold and warm blooded animals?—The proportionate size of the lungs and the number of the air-cells or vessels. In the warm-blooded variety the air-cells are larger and more numerous than in the cold-blooded.

How is blood produced?—By the digestion of the various dead and inert animal and vegetable substances ingested into the stomach, and their conversion into an animalized and a vitalized fluid qualified to enter into the current of the blood, which is thus transmuted into living solids and fluids, by the process of assimilation to the existent solids and fluids of the body.

Why does the blood circulate in the body?—That it may supply and renovate the loss of those parts and particles which the animal machine is continually and unceasingly sustaining from decay, waste, the exercise of its different functions, and a variety of causes that are incessantly impairing or dilapidating it. It is thus that the vitality of the body is produced.

Why has the body muscles?—Because by their contraction and extension they give motion to the bones.

Why has the body nerves?—Because they give direction and force to the muscles.

WHAT is the use of bloodvessels?—THEY supply the nerves with life and energy, by furnishing them with blood.

WHY are the hairs of use to the body?—BECAUSE they keep open the pores, and serve as so many capillary tubes to conduct the insensible perspiration or excretion from the skin. Besides, being bad conductors of heat, they protect the head from the effects of the atmosphere, and tend to preserve the necessary temperature of the brain. It was for the purpose of modifying the violent passions of their adepts or novices, not for depriving them of the energies of their minds and passions, that the institutors of the monastic orders and the despots of the east ordered the heads of monks and eunuchs to be shaved.

WHY are the pores of use?—BECAUSE, by their medium, the excrementitious matter of the blood being removed, the superfluous moisture of the body is evaporated by means of insensible perspiration or excretion. Besides, the pores, in conjunction with the lungs, have the power of preserving the due temperature of the body (namely 93°) under all changes of the temperature of the weather; the one carrying off, by the increase of the perspiration, the excess of heat, while the other (namely the lungs), by the decomposition of the air, supplies any undue loss which may happen in cold weather.

WHY is perspiration of use to organic bodies?—BECAUSE it carries off the impurities of the body, as the waste and refuse of the bones, the muscles, the blood, and the food.

WHY are the senses of hearing, seeing, smelling, tasting, and feeling given to animal nature? — THAT the respective species of animated nature may enjoy their existence in the most perfect manner.

WHY do we feel the sensations of heat and cold from the weather or from fire?—BECAUSE in hot weather our bodies absorb heat or caloric from the atmosphere, and in cold weather their heat or caloric escapes into the atmosphere. For the same reason, that is, the difference of temperature between our bodies and the fire, do we experience the sensation of heat from fire; a portion of the heat of the fire being abstracted and conducted away from it by the coldness of our bodies and imparted to them. For the same reason also is the sensation of cold felt when the hand grasps a body colder than itself, or of heat when it grasps a body hotter than itself; and that in the first case the sensation of cold, and in the second that of heat continues until the same temperature is established between the hand and the object; and in both cases the intensity of the sensation is felt when once established in proportion to the superior or the inferior conducting power of the body grasped.

WHY does violent exercise or hard labor occasion heat, and produce perspiration? — BECAUSE, the organs of respiration respiring with greater activity or more rapidly, a greater quantity of oxygen is inspired, which uniting with the carbon of the blood produces in it an increased caloric, and consequently a greater excitement and heat are produced in the body.

WHY is the feeling of touch so very exquisite on the tips of the fingers and the lips?—BECAUSE those parts are thickly studded with minute bloodvessels and branches of nerves.

WHY is eating of use to the body?—BECAUSE the waste of the body occasioned by perspiration and excretion is renewed by fresh additions of blood.

How are the remora or fæces evacuated from the body?—BY the peristaltic or vermicular action and motion of the intestines.

WHY is drink of use to the body?—BECAUSE it supplies the loss of moisture produced in the body by perspiration and other discharges, and by assisting digestion furnishes the moisture necessary for the repair of its tissues.

How is hunger occasioned?—BY the gastric or stomach juice requiring food to prepare for the production of blood; otherwise it acts on the coats of the stomach and produces derangement of the system.

WHY, in cold weather, is the human and the brute creation more liable to the sensation of hunger, and in hot weather to that of thirst?—BECAUSE, in the first case, of the escape of the caloric generated by the food; and in the second, of the increased sensible perspiration.

WHY is a starving man when exposed to the inclemency of the weather more quickly frozen to death than a well-fed man?—BECAUSE of the less degree of generation of caloric in his body.

WHY is a person, when badly clothed, more hungry than when well clothed?—BECAUSE of the more rapid escape of the caloric.

WHY in cold weather is the urine more abundant and the disposition to secrete it more frequent than in hot weather?—BECAUSE of the diminution of the insensible perspiration, or rather its almost total suspension.

WHY does a child require food oftener and bear hunger less easily than an adult?—BECAUSE its organs of respiration are more active.

WHY does the body during labor require more food for the supply of the system than when it is inactive?—BECAUSE the number of respirations is greater in exercise than when the body is in a state of rest.

WHY is the body of the same weight at the end of the day as at the beginning, notwithstanding the quantity of the food ingested?—BECAUSE the escape of the quantum of the insensible perspiration is equal to that of the nutritive part of the ingesta.

WHY is the body subject to lethargy and somnolency after heavy meals and the use of beer, wine, and tobacco?—BECAUSE the blood carried to the brain is overloaded with the carbon produced by the excess of the food, drink, and the fumes of the tobacco.

WHY can the serpent live without food for three months or longer?—BECAUSE of its sluggish respiration. It is from the same cause that dormant animals, birds, and insects preserve vitality during their hybernation.

WHY is strong exercise, or mental application, improper during or immediately after a meal?—BECAUSE it diverts the flow of nervous energy and of blood to the stomach, and consequently retards or stops the process of digestion.

WHY is severe muscular exertion or close mental application improper before meals?—BECAUSE, in the first case, the flow of the nervous energy and of the circulation being strongly directed to the muscular system; and in the second case, the energy and circulation being directed to the brain, the stomach is called into action without being possessed of its necessary powers and energy.

WHY is conversation during a meal of use in the process of digestion?—BECAUSE the play of the diaphragm and the abdominal muscles is thereby promoted, and thus the necessary agitation, or churning, of the food assisted. The active and energetic respiration attendant on cheerfulness and buoyancy of spirits assists the power of digestion, and pleasing emotions increase the nervous stimulus of the stomach.

WHY does despondency, grief, or depression of mind enfeeble digestion?—BECAUSE they diminish the vivacity and extent of the respiratory movement.

WHY do we feel chilly on the surface and at the extremities of the body after a hearty meal?—BECAUSE the blood and nervous energy are abstracted from the external part of the body to assist the stomach in its office of digestion, it being a law of vital action, that when any organ is called into extraordinary activity an increased flow of blood and nervous energy immediately takes place towards it. For the same reason we feel an inactivity of both body and mind after dinner, because that energy and activity which support muscular and mental exertion are concentrated for the time on the organs of digestion.

WHY do the nations of the northern regions of the world live chiefly on animal food, and drink strong liquors, while those of the southern regions live chiefly on vegetables and fruits, and drink more simple beverages?—BECAUSE the first have need of stimulus, the second not. Or to be more explicit, those who inhabit cold damp climates require the strong and exciting nourishment contained in animal food for maintaining the system in its proper vigor; while lighter and more easily digestible food is necessary for people in warmer climates, in order to avoid the stimulating and injurious effects which would result to the constitution from the consumption of strong food and drink. It is for this reason that the inhabitants of France, Spain, Portugal, and Italy, the Arabs of the Desert, the natives of India, and the population of all warm countries live chiefly on vegetable food and light drink, while the Germans, the Russians, the Dutch, the Esquimaux, the Icelanders, and the inhabitants of all northern

regions consume large quantities of animal food and indulge in potent drinks.

WHY are sleep and rest necessary?—BECAUSE the powers of nature require time to recover the exhaustion and to repair the wasted energies which the exertions of the mind and body have occasioned.

WHY is exercise of use to the body?—BECAUSE it reanimates the strength of its organs and increases the vigor of the vital system.

WHY is bathing conducive to health?—BECAUSE, as it occasions the skin to shrink, and the whole of its tissues to contract, the capacity of the cutaneous system for the retension and circulation of blood is diminished, and a portion of the blood circulating through them is suddenly thrown upon the deeper parts and the internal organs. The nervous system participates in the result, and being stimulated by the efflux, communicates its impression to the whole of the system by imparting to the heart and bloodvessels a more energetic action; and thus the internal organs are relieved, the tone of the muscular system increased, and the whole organism invigorated.

WHY are rest and quietness favorable to mental or intellectual exertion?—BECAUSE motion dissipates the thinking faculty, and disorders the intimate connection which subsists between that faculty and our corporeal frame. This fact is forcibly illustrated by the anecdote related of Cunningham by Mr. Thomson, in the introduction to his translation of that author's History of Great Britain; namely, that Cunningham and Lord Sunderland being great chess players, they frequently amused themselves by playing at that game while they were resident at the Hague. For this purpose whenever the peer was at leïsure he either drove to Cunningham's lodgings, or sent his

carriage for him. After thus amusing themselves for a course of time, Lord Sunderland observed, that he who was jolted in the carriage was always sure to lose every game; for which reason he always sent for his playmate, and the consequence was that he always beat him at the game. Cunningham, who was conscious that he understood the game as well as his adversary, began to get out of humour, when to restore his temper Lord Sunderland told him the secret, at the same time proposing that they should meet at each other's lodgings alternately,—a circumstance which restored Cunningham to his former level of skill; for from that time they won and lost alternately. Intense and long-continued heat and cold have the like effect on the intellectual faculty.

WHY is clothing of use to the body?—BECAUSE it contributes to its health and comfort by intercepting the too rapid radiation or evaporation of the heat of the body, and the escaping of it faster than it is generated; thus preventing the changes of the atmosphere from affecting the system. The natural covering of wool, hair, and feathers given to the dumb creation effects the same purpose as clothing to the human body. The vulgar error of supposing that there is a positive warmth in the materials of clothing is disproved by the fact that while flannel is the article of winter clothing most productive of warmth in our climate, the cold necessary to prevent ice from melting in summer cannot be produced so effectually as by wrapping the vessel containing it in many folds of the softest flannel. The placing of layers of straw or matting upon plants and garden beds is adopted for the same purpose, namely, to obstruct radiation or escape of their heat, and thus prevent their being chilled.

WHY does the body require a greater quantity of clothing when we lie down or are in bed than when we are in motion?

—BECAUSE when asleep, or in a state of rest, the circulation and breathing are slower than when we are awake, and consequently the animal heat of the body is diminished. It is for this reason that when we lie down in our clothes on a sofa or in the open air we feel chilled and uncomfortable on waking.

WHY is linen preferable as a bandage for a cut or wound to cotton?—BECAUSE the fibres of which linen is composed are perfectly round, soft, and pliable, and from the porous quality of its texture it easily absorbs the blood or matter which issues from the wound. Cotton, on the contrary, is apt to irritate the skin when grazed, because its fibres are flat and have sharp edges, and it has not the quality of absorbing moisture like linen.

WHY do moderately loose garments afford more warmth than those that fit tightly?—BECAUSE a thin stratum of air is enclosed between each layer of clothing, which tends to retard the passage of heat from the body.

WHY is cotton warmer than linen?—BECAUSE it has a less tendency to absorb and conduct the heat of the body.

How is old age occasioned?—BECAUSE the body gradually decays; or, rather, the leading cause of old age is the obliteration and obstruction of the smaller or fine hair-like bloodvessels which branch out in every direction through the muscles and skin, whereby the blood is prevented from reaching all parts of the body to supply them with the requisite nourishment. The same minute vessels which branch through the glands become similarly obstructed, and the supply of the peculiar secretions is diminished or dried up in consequence of their being stinted in the supply of fresh blood from which those secretions are produced.

WHY are schoolmasters, loquacious persons, and all those who

exercise the voice much, long lived?—BECAUSE the expiratory function is constantly and fully exercised by them, and consequently the circulation of their blood is comparatively well sustained.

WHY are cheerful company and all excitement of an agreeable kind salutary?—BECAUSE they serve as stimuli to the circulation.

WHY are the depressing passions detrimental to health?—BECAUSE they retard the circulation and determine the blood to the chest in so great quantities as to prevent its being thoroughly oxygenated.

WHY do fear, anxiety, and various other depressing passions diminish the power of digestion?—BECAUSE they stop the secretion of the gastric juice. The diminution of the secretion of the saliva is also subject to the influence of the same mental emotions as affect the digestive functions of the stomach.

WHY do we feel that weary sensation to which we are subject if we remain in one posture, either sitting or lying?—BECAUSE a considerable portion of muscles are in a constant state of contraction by the body remaining in one posture.

How are the phenomena of spectral illusions occasioned?—BY disease in the brain, organic mental disorder, a defective condition or an unusual sensitiveness of the retina of the eye, hysterical and epileptic affections, disorder or a deranged condition of the alimentary organs, or digestion, producing delirium tremens, a plethoric state of the bloodvessels, or some bodily derangement in which the senses sympathise.

WHAT is the cause of the diseased mental function termed *second sight*, or the spectral appearances of those who are doomed soon to quit this mortal scene?—IN addition to some of the above mentioned causes, derangement of the brain or of the

nervous system, solitude, or the imagination being led astray by ruminating on the causes of human weal and woe.

WHAT occasions the phenomenon of the luminosity which sometimes (especially in severe cases of pulmonary consumption) hovers over and about the bed of persons in the last stage of the disease?—IT is probably occasioned by the discharge or evolution of gaseous vapours, either through the pores of the skin, or with the breath, and their combination with the atmospheric air.

WHY, in battle and during thunder storms, are persons sometimes killed, without any visible marks of injury being seen on them, even though it is evident that they have not been struck by a ball or the lightning?—BECAUSE by the vacuum which the passage of the electric fluid or the ball has made in the atmosphere, the vital air of the lungs has been extracted.

WHY does the flesh swell in warm weather, the skin distend, the bloodvessels appear filled, and the hand plump?—BECAUSE the blood flows or determines to the skin and distends its vessels.

WHY is a greater quantity of oxygen necessary for the consumption of animal nature in cold than in warm weather?—BECAUSE in cold weather a greater quantity of heat is necessary for the sustentation of animal life, and therefore the wants of the animal system require a greater quantity of oxygenic air for the generation of the requisite quantity of carbonic acid gas to preserve the equability of temperature necessary for the sustentation of life.

WHY in cold weather, when the body has been exposed to the open air, does the flesh appear to contract, the bloodvessels to shrink, and the skin to shrivel?—BECAUSE the blood flows or determines from the cutaneous vessels to the internal and vital organs of the body.

WHAT occasions the difference of complexion in the human countenance, namely, that some persons are of fair and others of dark complexions?—FAIRNESS of complexion is dependent on the arterial circulation, darkness on the venous circulation; the arteries possessing in fair persons the greater energy, while in the dark the veins are more developed, larger, and fuller.

WHAT occasions the variety of form, stature, feature, and complexion in the human form?—THE peculiar circumstances and the physical conditions in which persons are placed. The variations that have arisen from the primeval stocks in the races of mankind and the various orders of the animal creation have been occasioned by the difference of climate, food, civilization, and peculiar training. That external circumstances have great effect to produce variation, even as to colour of the skin, is evident from the case of the Hindoos, who are of every shade of colour, the shades being the effect of the comparative height of the temperature of their respective localities. In both animal and vegetable nature distinct varieties can be produced by selecting kinds, and breeding from them alone, and the degree of education or civilization bestowed on them. Among domesticated animals and in cultivated vegetable economy new varieties are being constantly thus produced. But though the properties of life are by these means subject to different modifications, the rudiments of the natural identity of the primeval stock always remain.

How have the characteristics or personal differences in the shape of the head, the cast of the features, the colour of the skin, and the colour and quality of the hair, of the five great races of mankind, namely, the Caucasian, the Mongolian, the Ethiopic, the American, and the Malay varieties been produced?—BY the effects of climate. The supposition that these effects

are produced, in conformity to certain laws, according to the necessity and operation of local circumstances, receives weight from the fact that the features of the descendants of Africans in the United States, after three or four generations, lose much of the native African cast, and approximate to those of the white people, the mouth becoming smaller, the eyes lively and sparkling, the nose higher in the ridge, and the hair considerably longer and less crisp. The Nubians also, though perfectly black, have no resemblance in their features to the Negro race, and have oval, regularly formed, and handsome faces. The variety of colour in the skin of the Negro and other dark races is said to depend on the colouring matter situated in those races beneath the rete mucosum, the second of the three integuments of which the human skin consists.

WHY is it evident that the structure, stature, and strength of the human race were always the same as they are at present, and consequently that men of gigantic stature never existed on the earth?—BECAUSE as the materials and power of which the human frame is constituted are adapted to the expenditure of the material and exertion for which it was designed, a longer frame would of course require a structure of stronger materials, or it would be destroyed by its comparatively greater weight.

WHAT is the average weight of the human body?—WHEN well nourished, and of a medium size, it is about 160 lbs., or between eleven and twelve stone; there are instances, however, where it has weighed from thirty-five to forty stone. Dr. Cheyne mentions an instance of thirty-two stone. In the Philosophical Transactions two cases are recorded of 480 lbs. and 500 lbs. And in the Breslau Collections two cases are mentioned, one of which weighed 580 lbs. and the other 600 lbs.

WHAT is the average weight that a man of ordinary size

can carry?—From 150 to 200 lbs. The strength of weak men is equal to 125 lbs.; that of very strong men to 400 lbs.; but the strength of Topham was equal to 800 lbs.; and the Albanian porters, employed at Constantinople, will carry from 800 to 900 lbs. on their backs, stooping forward, and assisting their steps with a short staff.

What is the average duration of human life?—In the best tables it is stated,

That a person	1 year	old may live	30	years.
„	5 years	„	42	„
„	10	„	37	„
„	20	„	34	„
„	25	„	28	„
„	30	„	28	„
„	35	„	25	„
„	40	„	23	„
„	45	„	20	„
„	50	„	18	„
„	55	„	15	„
„	60	„	13	„
„	65	„	10	„
„	70	„	8	„
„	75	„	6	„
„	80	„	4	„

What is the average mortality of the human race?—According to Susmilch, one in thirty-six. In Europe the average annual deaths are one in twenty-three in large cities; in moderately sized towns, one in twenty-eight; in the country, one in thirty-five; in the most healthy parts one in fifty-five. The average annual deaths in England and Wales are one in sixty. The country that approaches the nearest to us in

its general salubrity is the Pays de Vaud, where the mortality is one in forty-nine. In France, one inhabitant dies annually in forty. The kingdoms of Prussia and Naples range between thirty-three and thirty-five. The annual mortality of Nice, though reputed salubrious, is one in thirty-one; Naples, one in twenty-eight; Leghorn, one in thirty-five. The average mortality of the great cities of Europe is as follows:—In London, the annual deaths average one in forty; in Paris, one in thirty-two; in Lyons, Strasburgh, and Barcelona, the same; in Berlin, the average mortality is one in thirty-four; in Madrid, one in twenty-nine; in Rome, one in twenty-five; in Amsterdam, one in twenty-four; and in Vienna, one in twenty-two and-a-half. In old age, the duration of female life is greater than that of males.

*** In England, the number of births is about one thirty-ninth part of the population. The probable duration of life on the birth of a child is 38 or 39 years. The proportion of births of males and females is about 18 to 17; but the proportion of the female population to the male population is as 19 to 18. The proportion of children to every marriage is about 3½; and the average number of persons to every family is about 4½.

WHAT is the average duration of the life of animals?—

THE cricket lives..	10 years	The carp ..	100 to 150 years
The spider, sometimes more than	1 year	The pike, sometimes more than	40 „
The scorpion, generally, but sometimes more than	1 „	The crocodile	100 „
The river cray-fish.	20 years	The tortoise (one lived to the age of 107).....	100 „
The hen	10 „	The hog	20 to 30 years

The pigeon	8 years	The cat	10 to 18 „
The peacock.....	24 „	The squirrel	7 „
The turtle-dove ..	25 „	The hare	7 to 10 „
The nightingale and the lark ....16 to	18 „	The dog.....	14 to 28 „
The canary, if it does not couple.	24 „	The wolf	20 „
The canary, if it breeds annually.	16 „	The bear. upwards of	20 „
The sparrowhawk .	40 „	The fox	14 to 16 „
The partridge	25 „	The lion (Pompey lived to 70)....	60 „
The goose ... 50 to	80 „	The cow, sometimes more than	20 „
The swan.. 100 to	300 „	The bull	30 „
The eagle (one died at Vienna at the age of 104) ...	100 „	The ox.....	19 „
The raven	100 „	The deer.....	20 „
The parrot.....	110 „	The horse (one has been known to live to the age of 62)	25 to 30 „
The pelican	„	The ass	25 to 50 „
The rabbit. from 8 to	9 „	The camel.. 50 to	100 „
The goat	10 „	The elephant, 150 to	400 „
The sheep.....	10 „	The rhinoceros ..	20 „
The ram	15 „		

WHY do some insects walk and small needles float on the surface of water?—BECAUSE their weight is not sufficient to overcome the cohesion of the particles of the water.

WHY do the bodies of water-fowl float on water?—BECAUSE their bodies are lighter than their own bulk of water. Their feathers also contribute much to their buoyancy. Fish, from their capacity of enlarging and contracting their dimensions by the distension of the air-vessel with which they are pro-

vided, rise to the surface or sink to the bottom of water, being enabled thereby to displace a greater or a less quantity of water than their own weight or bulk.

WHY are fish of a wedge-like form?—THAT they may be enabled to glide with ease and rapidity through the water, that form being the best adapted to remove obstructions.

WHY do cows with small and slender horns, and goats whose horns have been artificially removed, supply milk in greater quantity, and of better quality, than cows with large and exuberant horns, or goats whose horns are allowed to remain?—BECAUSE the nourishing fluids which the growth of the horns consumes have been diverted to the formation of milk and flesh.

WHY is the neck of the elephant short?—THAT his head may be supported; its weight being too heavy to be supported at the end of a long lever.

OF what use are the humps on the back of the camel and the dromedary?—As stores of nutriment, in the case of the scarcity of food. These humps, which consist of fat, are observed to be gradually absorbed, and to disappear in the course of their journeys through the sandy deserts, in the event of a scarcity of food. The supposition of Buffon, that the humps were for the purpose of enabling the animals to support drouth in their journeys through the desert, is unfounded.

WHY is the body of the mysticetus, or Greenland whale, surrounded with the prodigious quantity of oil to the amount of thirty tons, while that of its congener the cachelot, or spermaceti whale, has only four tons?—1st. BECAUSE its body being of less specific gravity than water, the mass of oil augments the buoyancy of the whale's huge frame. 2ndly. Because it tends to keep the animal temperature from being rapidly lowered

by the conducting power of the water, the animal's conducting powers being very feeble. And, 3dly, Because it enables the animal to resist the enormous pressure to which its body is subjected at the depth to which it often descends.

For what purpose is the head of the cachelot, or spermaceti whale, filled with the mass of oil (namely, a ton in weight), which, when it has concreted by cooling, becomes the spermaceti of commerce?—To assist the enormous bulk of which its head consists to float and preserve its relative equilibrium with the rest of the body.

Why are both bills in birds which have hooked beaks moveable?—Because if only the lower jaw was moveable, they would not be able to open their bills wide enough to receive their food.

Why have fowls, ducks, geese, pigeons, &c. a gizzard?—Because it supplies the place of teeth (which they want) by breaking and grinding their food by means of the friction of its rough plates.

Why are the incisors or front and the cheek teeth of carnivorous animals sharp, and those of the herbivorous species flat?—Because those of the first-mentioned species may enable them to tear and rend the animal food they feed on, and those of the last-mentioned to enable them to grind the grass and pulverise the grain which constitute their food.

Why can certain animals, as otters, the alligator, the hippopotamus or sea-horse, &c. and fishes remain under water for a certain time without apparent respiration?—Because there are in the organisation of their respiratory organs certain vessels which receive a portion of the blood thrown upon the lungs and gills by their diminished circulation, and that it remains there until their full respiration can be again performed.

WHY are certain animals, birds, and insects, as bears, the fat dormouse, swallows, bees, flies, &c. enabled to preserve life during the winter months while in their torpid state?—BECAUSE the heat of their blood scarcely exceeds that of the temperature of the surrounding air.

How are animals, birds, insects, &c. enabled to support life during their hybernation, without food or sustenance?—BY the absorption into the system of the fat accumulated during the summer months.

WHY are birds able to fly?—BECAUSE, independently of their pinion-feathers, their bones are more hollow than those of animals that do not fly, and in proportion to their weight they have the largest bones of the animated creation. They are also, when they wish to descend, rise, or float in the air, enabled to proportionately extend their bodies. The muscles, to enable them to move the wings downwards, are also very large, in many cases being a sixth part of the whole body, whereas those of the human frame are not proportionately one-hundredth part so large.

WHY do birds and quadrupeds annually moult and cast their hair?—To replace the feathers and hair lost in the course of the year.

WHY are the bones of animated creation of different forms?—To adapt them to the various actions and directions in which the joints are to be used and exerted, and to suit them to the various forces which may be applied to them.

WHY have Albinoes, whether consisting of the human race or of quadrupeds and birds, white hair or feathers, and eyes of a glassy red hue?—BECAUSE of the peculiarity of the colouring matter of the skin. As the colour of the eye is dependent on the nature of its mucous pigment, the peculiar colour of the

Albino eye is occasioned by the deficiency of that constituent of visual colour.

WHY are eels longer-lived out of water than other fish?—BECAUSE their external gill-apertures being very small, and opening very far back, they are enabled to keep the gills moist for a long time when out of water.

*** This power of the retention of life is not peculiar to eels. Other orders of the animal creation exhibit a greater degree of sustaining the power of life. Thus the tribe of insects denominated Malesoma is so tenacious of life, that individuals have been known to remain alive for six months without food, and stuck on a pin. The land-crabs of the West Indies are invested with a special provision of a sponge-like substance in the interior of the cavity which encloses the gills, for keeping the gills moist for a considerable time when they quit the water.

WHY are all kinds of ruminating cattle continually eating in the winter season, whereas in summer-time they lie down after eating and chew the cud?—BECAUSE in the winter season the nutritious principle of the grass or other pasturage on which they feed is not so well developed or evolved as in the summer season, and therefore they then require a greater portion of food to satisfy their appetite than they do in summer-time.

WHY does the gossamer spider support itself in the air without wings?—BY means of its web, which is lighter than air; and thus the body of the insect, though heavier than air, is buoyed up by it, as the body of a kite is buoyed up by the tail of the kite.

WHAT produces that substance called *gossamer web*, which is found floating in the air in fine weather in autumn?—IT is

the thread or web of the gossamer spider, with which it sails through the atmosphere.

How have toads, worms, frogs, snakes, lizards, bats, flies, fish, &c. been introduced into the very heart of the oak, the elm, cherry-tree, &c. and into the very centre of large blocks of stone, marble, and ice?—THEIR inclosure in trees has been accomplished by their having taken up their abode in a chink of the tree at the season of their commencing torpidity, and by the chink having closed during their torpor or dormant state; and their enclosure in blocks of stone, marble, and ice has been occasioned during the sedimentary formation or deposition of the stone or marble: in both cases the vivifying principle was suspended or preserved until it was submitted to the agents calculated to call it into activity.

WHY will not fish kept in a vessel, or an ornamental basin, live unless the water is frequently changed?—BECAUSE the water becomes so charged by their respiration with carbonic acid gas as to be deleterious. The case is the same in all streams and natural sources of water, unless there is a sufficient number of aquatic vegetables in them to take up the carbonic acid gas, so as to prevent the water from becoming poisonous.

WHAT enables the salamander to live for some time in fire with impunity?—THE defence which the slimy fluid it throws out from all parts of its body presents to the effects of heat.

WHAT occasions the fascination of birds and the small animals that serpents prey on?—SUDDEN fear or the stupefaction produced by the poisonous and fetid exhalation emitted by the serpent.

WHY is the pupil of the eye of ruminant animals in the form of an horizontal oblong?—To increase the range of vision along the surface of the earth, so that the animal may be

readily apprised of approaching danger while in the act of feeding, as also for ascertaining the proximity of food in any direction. Their ears partake of motion for the same purpose.

WHAT enables the humming bird, the crow, and the parrot to talk?—THE complicated structure of the larynx, or organ of voice.

WHAT occasions the change of color in the cameleon, and why is it endowed with the power of assuming the color of the leaves over which it is gliding?—ITS change of color is principally occasioned by an alternation in the relative position of two layers of coloring matter which the skin contains, so that they may be displayed singly or in various degrees of combination; and its power of assuming the color of the leaves over which it is gliding enables it to approach the flies, beetles, and other insects which constitute its food, without being perceived. Thus, when it passes among green leaves, it is of a green color, and when it glides by any of a red or yellow tinge, it changes its hue to red or yellow.

*** Other animals of the lizard order possess the power of changing color in a greater or less degree.

WHY do zoophytes, as polyps, earth-worms, and other inferior orders of the creation, when separated or cut into pieces, live and possess the wonderful property of reproduction?—BECAUSE each part possesses an individual and independent existence.

II.—VEGETABLE PHYSIOLOGY, OR BOTANY.

Vegetable physiology is the science which explains the nature and properties of plants, the phenomena of their origin, their internal and external organization and structure, their functions, growth, nutrition, produce, specific characters and uses, their decay, reproduction, and regeneration. As the animal body consists of solids—namely, flesh, bone, and muscle,—and fluids, so the body of a plant bears an analogy to it in its organization and structure, being composed of tissues of cells, fibres, and vessels which constitute its solids; and of sap, analogous in its office to the blood of the animal machine. The bark, with its skin or rind, bears a resemblance to the scarf-skin with its epidermis or cuticle.

As has been appropriately said, "a striking analogy or "resemblance exists between the animal and the vegetable "systems. Thus, the animal creation has its nutritive and "digestive system—its circulating system—its respiratory "system—its nervous or sentient system—and its generative "or reproductive system. In like manner, the vegetable "creation consists of a series of subordinate systems, but "much more simple in their construction—all concurrent to "one great end—life. For this purpose, it has its circu-"lating, aërating, digestive, sentient, and reproductive orga-"nizations. Its fibres or woody tissue are analogous to the "bones of the animal machine, its albumen or sapwood to "the flesh, its sap to the blood, and its bark and corticle to "the animal scarf-skin and epidermis. It has also organs of "reproduction, is subject to derangement and disease, to "decay and extinction or death, and moreover to the power

" and capacity of renovating and perpetuating its species. " In analogy to quadrupeds and birds shedding their hair and " feathers as the winter approaches, the various species of " plants cast their leaves. Like the hybernization of many " quadrupeds, reptiles, and birds, vegetable nature passes the " inclement season of the year in a state of inactivity and " repose. And a resemblance or analogy not only exists in " the organisms and functions of the animal and vegetable " systems, but a close approximation takes place in many " other instances. Thus, many animals have in their structure " or organization no characteristic of animated nature; and " others have been discovered which seem to be incapable of " moving themselves from the spot on which they were produced. " Some also are found to be so apathetic as scarcely to manifest " any feeling of injury when severely wounded. Many of " the Conchiferæ are attached to one spot during all but the " earliest periods of their existence. The Molluscs of the sea " and the Zoophytes of the earth are destitute of locomotion. " All the tribes, except the Echinodermata of the Radiata, " live, grow, and multiply very much in the same manner " as plants; it not being possible to ascertain with any cer- " tainty whether the feeble motions which they exhibit are to " be regarded as spontaneous or not. The class Acephalæ " of the sub-kingdom Radiata imbibe their element like plants " by root-like filaments; others by absorption through the " medium of their exterior. Some tribes of animated nature " partake both of an animal and a vegetable property. Thus, " Zoophytes, by their external configuration, their remaining " in one place, and their reproduction by buds and seeds, " resemble plants; like them they may also be propagated by " grafts and slips. Their animal nature appears from their sen-

" sibility and voluntary motion." — *Botanical Science Simplified.*

WHY do vegetables, flowers, and trees produce leaves and fruit in summer?—BECAUSE heat revives their natural energies and properties after the sleep of winter, and their air-vessels expanding, the juices ascend from the roots, and invigorate or supply the plant or tree.

WHY do plants perish above ground as the winter approaches?—BECAUSE the sap or juice of trees or plants descends towards the roots, in order to supply them during their winter-sleep, and produce the renovation of their powers.

WHY do leaves of trees appear at different seasons of different colors?—BECAUSE their natural color, green, partakes of and is modified by the color of the objects by which they are surrounded in the degree or proportion that their surfaces are polished or rough, the polished foliage reflecting the color of the surrounding objects, (thus having its own verdant hue neutralized,) but the rough absorbing or neutralizing it. It is for this reason that the color of foliage sometimes appears of a blueish cast, the azure of the sky being reflected to the eye from the polished surface of the leaves, and thus the true tint of the foliage being modified, is lost; and this optical illusion arising from reflected color is stronger in tropical or warm countries than in temperate climates, because there the azure tint of the sky is very intense.

WHY do plants and flowers grow on turning up the soil from great depths, or on breaking up a tract of ground that has lain uncultivated within the records of history, and why, on the destruction of forests by fire, does a growth of trees of quite a different nature from those which were consumed, sponta-

neously take place ?—BECAUSE the seeds which once grew upon the ground, and which had long lain dormant at a depth in the ground, recover their germinating power, and their organic structure is disintegrated, when they are submitted to the agents that tend to call them into activity, such as exposure to the influence of the sun, air, and light, or the action of some compost or manure; their vitality having been suspended or dormant while they remained buried in the earth. In the act of boring the ground at Kingston-upon-Thames, mould was brought from a depth of 360 feet, which, when exposed to the action of the air, was quickly covered with plants from the germinative power of the seeds being resuscitated. But no explication can be given, why, when the original growths of the forests of the Canadas, Nova-Scotia, and the whole table-land of North America have been consumed by fire, a new set of saplings of a different species have sprung up; that is, where forests were once covered with pines, after their destruction by conflagration, white birch, spruce fir, poplars, wild cherries, &c., have spontaneously sprung up; a phenomenon not peculiar to those regions, it having been observed also in England. Evelyn, a writer of the seventeenth century, says, "that when his grand-"mother's woods were cut down, which consisted entirely of "oak, there sprang up again not oaks, but beeches; and when "they in their turn felt the axe, there arose spontaneously a "third plantation, not of oaks or of beech, but of birch."

WHY do successions or rotations of the same crops, particularly of the same kind of grain, fail in their vigorous condition and produce ?—BECAUSE each kind of crop has a specific deteriorating or injurious effect upon the soil, from the various matters which it throws off from its roots. In general all kinds of

grain succeed best after a crop which has been cut before the seed has ripened, or the stem has dried up. Those plants that have a naked stem with but few leaves thrive best after leguminous plants, which have more succulent stems and more leaves, and which bear their seeds in pods, as peas, beans, tares, or vetches; or after esculent roots, which strike deep into the ground, as carrots, turnips, beet-roots, parsnips, &c. Besides the general exhaustion of soils produced by vegetation, plants which bear oily or farinaceous seeds most exhaust soils. The reason that plants do not grow well successively in the same soil, unless changed by rotation, is, that all roots give off refuse or indigested matter, as may be seen in the case of hyacinths grown in water; the successive rotation of crops tends to diminish and remove that refuse.

WHAT occasions one species of tree to grow luxuriantly on some soils, while other kinds of tree can scarcely vegetate on the same soil?—BECAUSE of their superior abundance of alkalies or alkaline earths. Therefore, as pines and firs do not require so great quantity of alkali as oak does, (a fact ascertained from the circumstance that oak when burnt yields nearly three times the quantity of ashes that the same quantity of fir and pine wood does,) they thrive in granitic and barren sandy soils in which oaks will not grow.

WHY do stones and pebbles conduce to the fertility of soils?—BECAUSE they prevent too great evaporation, shelter the young plants in exposed situations, and reflect the light and heat of the sun.

WHY do whitened walls ripen the fruit on trees fastened against them better than unwhitened walls?—BECAUSE the heat of the sun is reflected from the wall upon the fruit, instead of being absorbed. It is for the same reason, that houses in

the south of France are covered with white plaster, because, as white reflects the heat of the sun, the houses are thus kept cool.

WHY does soil shadowed with thick leaves promote vegetation ?—BECAUSE the leaves attract carbonic acid vapours and prevent their escape. It is for this reason that a crop of potatoes, turnips, or vetches fertilizes, while corn and flax exhaust the soil ; and for the same reason corn thrives better when clover is sown with it.

WHY does vegetable culture improve the healthy condition of a country ; and why does a previously healthy country become unfriendly to health by the cessation of cultivation ?—BECAUSE plants promote atmospheric salubrity by the removal of the carbonic acid gas with which the air is impregnated, and occasion the renewal of that constituent of air termed oxygen.

WHAT is the cause of vegetables emitting carbonic acid gas ? —ITS production from the charcoal, which is a constituent of their structure. The same proportion of carbonic acid and its electrical influence is emitted by equal weights of vegetables and charcoal, which burns freely.

WHAT occasions the stems or trunks of some plants and trees to appear thickest in their upper parts or subsequent growth ?—BECAUSE the season was unfavourable at the commencement of their first production, but was favourable in their latter growth, when they had the advantage of an increased vegetable power.

WHY are volcanic and basaltic countries very fertile, though the earth upon them is very shallow ?—BECAUSE the soil contains much carbonic acid gas. It is for this reason that the vineyards on the Rhine and those in Sicily and near Naples, and the basaltic carses of Scotland, are so distinguished for their great fertility.

WHY do plants, vegetables, and flowers, thrive better when watered with rain or river-water, than with water taken from springs, pumps, or pools?—BECAUSE rain or river-water is more impregnated with carbonic acid and azote, or nitrogen, which are the chief food of plants. It is for the same reason that a shower of rain has a much greater effect on vegetation than mere watering has. Watering flowers from a garden-pot with a finely perforated rose is more beneficial to flowers than from one with coarser holes, because the water has a better opportunity of being impregnated with the nourishing gases.

WHY do slips and cuttings of trees and shrubs strike or take root more readily when the wood cleaves with difficulty in the direction of its length or the lateral adhesion of its vessels, than when it cleaves quite straight or longitudinally; and why is the cause the same with shoots or cuttings when cut in a slanting direction, than when cut horizontally?—BECAUSE in the first case the lateral structure, and in the second the greater surface presented by the extension of the cut, give greater facilities for an increased number of shoots.

WHY in winter is all vegetation at a stand?—BECAUSE it is arrested by the temperature of the atmosphere being below the freezing point, when the water, which is the principal nutriment of plants, is too solid to enter the vegetable tissue.

WHY does snow melt sooner at the foot of trees and plants than at a distance from them?—BECAUSE their roots possess a temperature higher than that of the air.

WHY are the great deserts of many countries destitute of vegetation?—BECAUSE the heat is so great that the earth is dried up, and cannot impart the requisite nutritive properties.

How have the silicified or petrified trees resembling snow-white columns, found in the Cordillera of the Andes at an

elevation of seven thousand feet above the level of the sea, been formed ?—By being covered with the sedimentary matter of streams of submarine lava, during the alternate depressions and elevations to which the continent of America has been subject by volcanic agency.

Why do plants possess a temperature higher in winter than that of the air which surrounds them ?—To enable them to resist the cold of winter, nature having given them the power of extricating for themselves an additional supply of caloric, and therefore the temperature of their roots is of greater elevation than that of the surrounding air.

Why is tilling of use to vegetation ?—Because it admits the atmosphere to penetrate the humus or ground, in order to impart to it the carbonic acid which is the support of plants until they acquire leaves.

Why is manure beneficial to the cultivation of vegetable nature ?—Because of its fertilizing effects on plants, produced from the nitrogen derived from the ammonia which all manures contain.

Why is watering plants in the evening prejudicial to vegetation ?—Because by means of the evaporation which takes place in the course of the night, it subtracts a portion of the heat or temperature which is an agent or a condition in the growth of plants.

Why are trees which have great thickness at the stem or branch enabled to resist the severity of cold and frost, while young trees perish ?—Because they have a greater number of layers of heart-wood or duramen interposed between the bark and pith, which, being the softest and moistest part of plants, is the most susceptible of cold.

Why are trees which have long tap-roots able to resist the

severity of cold and the intenseness of heat, while those that have short tap-roots are destroyed?—BECAUSE their fibres penetrate into soil the temperature of which is greater in both extremes of weather than that of those plants whose roots are nearer the earth.

WHY will not vegetation flourish in the neighbourhood of sea-coasts, whereas animal life acquires an accession of health and strength in such localities?—BECAUSE of the deficiency of carbonic acid in the air, which occasions the languishing of vegetable life on account of the absence of the necessary pabulum or food which vegetation requires for the maintenance of its healthy condition.

WHY do hyacinths grow better in water-glasses of a dark color than in uncolored glasses? — BECAUSE the roots of plants naturally require protection from the light. It is for this reason that plants trained to germinate either inside or outside of a glazed window, direct their roots inwards towards the apartment.

WHY do trees exposed to the wind spread their roots much farther on the windward side than on the sheltered side of the tree?—To enable the tree to form a secure holdfast, and also to counterbalance the weight occasioned by the branches spreading most on the sheltered side of the tree.

WHY do trees, when growing or planted close together, have no lateral but only upper branches, and shoot up to great heights without any knots in their trunk; whereas trees that grow or are planted in open spaces have numerous lateral branches, numerous knots, and are of much shorter proportional growth?—BECAUSE, in the first mentioned case, the lateral branches being excluded from the air and the sun are strangled and perish, and thus being deprived of them,

the trees have no knots; whereas trees that grow in open spaces and on eminences, having the free influence of the air and the sun, have many lateral branches, and thus become knotted or gnarled with many contortions. The pine forests of America and the north of Europe are specimens of the first mentioned variety; and the oak and hawthorn, which obtain only a few inches of additional height in a lifetime, of the second. The hardness or softness of timber is occasioned by the same causes. The wood of the lignum vitæ, of the oak, and of many other species, whose growth has been in the second situations, is as hard as iron, compared with the stately tree grown in a rich soil and a sheltered situation.

WHY are the leaves of vegetables green?—BECAUSE as the real color of carbon, which is one of the constituent parts of plants, is dark blue, while the tissue of the cells and vessels of which the body of plants is composed, is yellow; when the blue carbon is lodged in the yellow translucent cells, a green color is the result. Hence in spring, the newly expanded leaves, before they have had time to prepare much carbon, are yellowish. Or in other words, the general green of the vegetable world is occasioned by the union of iodine, which is contained in all plants, with the acids or alkalies; all the other hues and shades arise from various modifications of that compound, by various portions of those acids and oxides, and their combinations.

WHY are leaves of different shades of color? — BECAUSE of the different structure of the membranes of the respective trees or plants, and the different degree of oxygenation which has been produced on their constituent substances.

WHY in autumn do leaves assume various tints?—BECAUSE

the leaves being too feeble in their power to emit the oxygen in the day-time, which they have imbibed in the night, various acids are produced in them whose known action is to change blues to reds; and consequently, when the blue carbon which they contain becomes thus tinged, various shades of orange, and other combinations of red and yellow, are thus produced.

WHAT is the use of leaves?—THEY are intended as an extension of the surface of plants, in order to facilitate the preparation of those juices that are necessary for their growth and well-being.

WHY do leaves fall on the approach of winter?—BECAUSE as their growth is suspended during the winter season, and consequently the demand for increased nourishment necessary for supporting their growth in spring and summer is no longer requisite, the additional extension of their surface becomes unnecessary, and consequently their leaves drop for want of nourishment.

OF what use are the colors of the petals of flowers?—To preserve the temperature of the parts necessary for reproduction at the proper season.

WHAT occasions the varied colors of flowers?—THE action of the light and the solar beams on the oxygen accumulated in the petals, producing acids which turn it red, while the alkalies change it through all the shades of purple, violet, blue, and green, thus producing every shade from the purest white to the most intense red. Those plants which contain the greatest quantity of alkali in their ashes have the flowers yellow, blue, or greenish; and those that have an excess of acid have them of an orange or red color. The variety of colors is also increased by cultivation and by inoculation, produced either by

art or nature. Dahlias, pinks, carnations, and many other flowers are thus varied in their colors almost without limit.

WHAT occasions the flavour and odour of fruits and flowers?—THE action of the light and heat on their essential oils. The greater the light and heat are, the stronger is the odour and the more pungent the taste. When deprived of their agency some fruits become tasteless, but their flavour returns when they partake of their benefit. Thus apples, pears, or any other fruit gathered from rank-growing trees, and hidden by leaves, are insipid, compared with fruit gathered from a tree on the produce of which the beams of the sun can play. In a dull and cloudy season, the whole of the vegetable productions of nature are insipid; on the other hand, in a clear and sunny season they are rich and vinous. Even heat does not compensate for the action of light or the partial diminution of it; for fruits that are grown under glass are not so juicy as those that are produced in the open air, even though the kind and the degree of the ripening may be the same; and those that are forced by steam, though they may be more pleasing to the eye, are not so rich to the taste as those that are produced in the dry and open air.

WHY do the hearts or internal parts of lettuce, endive, celery, cabbage, &c. become white or blanched, and crisp, juicy, and succulent, by being tied up?—BECAUSE the light being thus excluded, the oxygen which they contain, as also the matter of which they are composed, is prevented from escaping.

WHY by cutting in the bark round fruit trees is abundance of fruit produced?—BECAUSE the rising of the sap is impeded, and nature, to counteract the state of depletion thus occasioned, produces an abundant crop.

WHY is the disposition of the fig-tree to drop its fruit when but half matured prevented by severe pruning, or if the tree is grown in a pot is the same result produced by cutting a few inches from the circumference of the roots?—BECAUSE a check is thus occasioned to the rising of the sap. On the same principle harvests and crops of grass are more abundant, and vines bear more luxuriantly, after long and severe winters.

WHY do nettles sting when touched; but why when wetted may they be touched with impunity?—BECAUSE the hairs that grow upon their leaves piercing the skin, pour an acrid and poisonous juice, situated at the base of the hairs, into the wound, whereby the skin becomes blistered; and when the nettles are softened by moisture, the hairs lose their elasticity and consequently their capacity for making an incision on the skin.

FOR what purpose are the long slender bristles or beards on each of the grains of an ear of barley?—To protect the ear from the effects of rain and moisture; because barley is a grain easily injured by wet, which if not carried off would cause the barley to sprout even while on the stalk, whereby it would be injured.

WHY is vegetable organization produced in so infinite variety?—BECAUSE it is occasioned by the peculiar habits, and the particular situations, circumstances, qualities, and constituent parts of the soil, which afford the respective constituents of this portion of animated nature sustenance and food.

WHY are the growth and increase of animal and vegetable life greater and more rapid in tropical than in temperate climates?—BECAUSE of the higher temperature of the atmosphere.

WHY are plants and animals belonging to warm and tropical climates found in cold or high northern latitudes?—BECAUSE they have been placed or deposited there by the changes or vicissitudes to which the earth is constantly liable.

WHAT produces all that beautiful variety and display of grain and curl, which appears in certain varieties of the mahogany and other woods?—IT is occasioned by the varied courses or directions of the vascular cells or vessels of those woods being cut at right angles when sawed and planed.

WHAT has occasioned the bodies of men and animals, and the trunks of trees, found in peat bogs and other places, and which have lain there for centuries, to be in a perfect state of preservation?—THE antiseptic quality of the soil derived from the presence of tannin, which latter has been produced by the decay of vegetables possessing astringent properties. It is owing to the same property that animal substances are preserved by salt, saltpetre, sal ammoniac, pyroligneous acid, &c.; and that offensive odours are absorbed, and partially deprived of their noxious properties, by chloride of lime.

WHAT is the number of known plants, trees, &c. in the world?—ABOUT sixty thousand. This number no doubt forms but a very inconsiderable portion of the existing varieties of vegetation on the face of the earth. "Nature," as has been sententiously said, "is a wise and provident economist; in her garden there is no waste"—no barren or unemployed spot;

"No place is empty, no void that is not full,"

from the finest sand to the flinty rock; from the burning plains of the torrid zone to the eternal snows of the arctic regions; from the summits of the highest mountains to

the depths of the deepest caverns; each soil and climate has its peculiar and appropriate vegetation—all teem with life both vegetable and animal, according to the nature and capabilities of their respective localities. The remotest and the most uninhabitable parts of the earth, as well as the darkest and most unfathomable depths of the ocean—even the arid sands of the tropical regions, where the heat of the sun is scorching, are no less prolific than the most fertile regions of the temperate zone. The inexhaustible fecundity of Nature in all her multiplied species abounds every where, and that too in the most infinitesimal space, according to the nature and conditions of localities. The burning sands of the tropical deserts have their oases garnished with limosas, the palm, or the tamarix. The polar regions, with their frost work of icebergs and eternal mountains of ice and snow, are clothed with their appropriate vegetation. In the ocean bed and on the surface of its waters, in the deepest mines and the darkest caverns, vegetation maintains her empire; all have their congenial vegetable vesture. And Nature is constantly working out her vast and magnificent purposes by means scarcely appreciable to the finite understanding of man. Among those means is the apparently spontaneous growth of algæ and other aquatic plants. This process, which is in accordance with the system of wisdom and benevolence prevalent throughout all the parts and arrangements of Nature, appears from the following easy and familiar illustration. Take a pond of water, and shut off its supply from rivulets and springs, and then observe the operations of Nature in filling it up. The sides and bottoms become speedily covered with a luxuriant crop of confervæ; other plants, which grow

only in water, begin to make their appearance, their seeds being wafted thither by winds or water; at length the superficial matting of herbage is able to support the weight of birds; grass grows, alternate vegetation and decay takes place, and finally the pond is filled up. This routine is observable in many small lakes which are fed by weak springs, and except for an artificial clearing out occasionally, they would in a short time become dry land. What, indeed, are extensive peat bogs and morasses but lakes and ponds choked up with vegetable matter, which remains in a half consumed condition? In a similar manner, and in an equal degree, the rudiments of animal life abound in the smallest particle of matter—in the cavity of a grain of sand, and in the circumference of the most infinitesimal globule of the purest water. "An animal world—

> 'Whose shape would make them, had they bulk and size,
> More hideous foes than fancy can devise,'—

consisting of various organisms of Infusoria, the minuteness of which is infinitely beyond mental power to form any conception of, exist and fulfil the purposes of their creation. The case is the same in the atmosphere, which is pregnant with hosts of microscopic forms of being, as infinite in number as they are varied in form, structure, and office or purpose; and even the rudiments of animated being are profusely scattered throughout the creation, awaiting their development by the decomposing influence of appropriate temperature and the other requisite conditions."—*Botanical Science Simplified.*

III.—MECHANICS.

MECHANICS (a word derived from the Greek μηχανη, a machine) is that science which investigates the laws and effects of the force, motion, gravity, or weight, and the equilibrium of solid and fluid bodies. When it relates to solid bodies, it is divided into the distinction of *Statics* (from σταω, I stand or am fixed,) and *Dynamics* (from δυναμις, power or force). When it relates to fluids, it is termed *Hydrodynamics*, (from υδωρ, water, and δυναμις, power,) which is again subdivided into the distinctions of *Hydrostatics* and *Hydraulics*. That branch denominated *Statics* will be the subject of the present inquiry.

The mechanical powers are six: the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw. The lever is the most powerful, because there is no limit to the difference of intensity in force of levers which may be placed in opposition to each other, except the length and strength of the material of which the levers are formed. The extraordinary power produced by a combination of levers is demonstrated by the fact, that a lever which makes one pound balance four, being applied to work a second lever of the same power, 1 lb. at the long arm of the first lever will balance 16 lbs. at the short arm of the second lever, and would balance 64 lbs. at the short arm of a third lever of similar power, and so on progressively; the power of the lever being in the same ratio as that of the descent of bodies through space. This power of the lever imparts the semblance of mathematical truth to the declaration of Archimedes, that he "would move the earth with his own weight had he a lever long enough and a prop

strong enough;" but a difficulty would still have remained for him; his motive power must have had the velocity of a cannon-ball continued for millions of ages to alter the position of the earth from its present course even a single inch.

WHAT occasions bodies or masses of matter to adhere together?—THE attraction of cohesion, or centripetal (*i. e.* centre-seeking) force, which is a power inherent in all material bodies, and dependent on the primary principles or laws of Nature.

WHY then do not the particles of which sand and powder, &c. consist, adhere together?—BECAUSE the grains are not in sufficiently close contact, that is, they touch one another in too few points to produce a cohesive attraction of their various particles, and to enable them to obtain a common centre of gravity, so as to preserve their stability.

WHY also does not a book, plate, or any other body placed upon a table, cohere to the table?—BECAUSE too few of the particles of their under surfaces come into contact with the table, in consequence of the unevenness of their surfaces, to produce a sensible degree of cohesive attraction. Plates of plate-glass often stick or adhere together on account of the contact of the great number of particles occasioned by the smoothness of their surfaces; and the polished faces of two hemispheres of metal can be made to adhere strongly together, if a few drops of oil are spread over their surfaces, so as to fill up the porosities or interstices.

WHAT prevents the particles of porous bodies from cohering together as strongly as those of dense bodies?—THE interstices which separate the particles of which they consist being filled with air, the spring or elasticity of which prevents the close union of the parts and their attraction of cohesion.

WHAT occasions the distinctions of hardness and softness of bodies; and that liquids are thick and thin?—THE different degrees of attraction of cohesion of the different substances.

WHY are some bodies (such as cork, sponge, and other porous bodies) more easily separated or torn to pieces than those which are dense, as stone, marble, iron, &c.?—BECAUSE fewer of the particles of which they consist come into contact with one another, so as to produce a sufficient cohesive attraction.

WHY is the water of the box in which grindstones are placed, swept and scattered out of the box in which the grindstone is, when the grindstone is whirled with great rapidity; and why, if the whirling motion be continued, does the grindstone break and fly to pieces?—BECAUSE the centrifugal (*i. e.* centre-fleeing) force is so great that it overpowers the attraction and the cohesiveness of the stone.

WHY does a round or globular body (as a ball of clay, putty, &c.) when rapidly whirled round on an axis or a spindle, bulge out at the middle, and flatten at the top and the bottom?—BECAUSE the whirling motion or centripetal force is greatest at the middle.

WHAT inclines bodies or masses of matter towards each other?—ATTRACTION of gravitation. It is by virtue of the tendency of the particles of which all bodies or masses of matter consist to arrange themselves around their respective centres by the law or influence of gravitation; that dew on the points of thorns, leaves, or blades of grass—rain and hail, and shot in its manufacture, assume a round or globular form.

WHY, then, if bodies gravitate towards each other, do smoke, steam, and vapour rise into the air instead of falling back on the ground, which according to the principle of the law of

gravitation they ought to do?—BECAUSE they are lighter than the air. When, however, they have reached a region of the air of their own density, they fall or gravitate, in obedience to the general law, to the earth: a fact visible in the neighbourhood of all large towns.

WHY is not the mutual attraction between the earth and the objects situated on it visible to the senses?—BECAUSE of the disparity of their magnitudes. Thus, the mutual attraction between the earth and a stone is not perceptible to the senses, because the size of the stone in comparison with that of the earth is too small to render the effect of gravitation of attraction sensible or visible.

WHY is the power of the attraction of gravitation inherent in the larger of two bodies?—BECAUSE the power of attraction between bodies is proportionate to their respective magnitudes, or, more strictly speaking, to the quantity of matter of which they consist. It is to the superior attractive power of gravitation of the earth, as being the larger body, that a book, an apple, or any other object, when dropped, falls to the ground. On account of the immobility of matter, were it not for the gravitating principle, bodies have no more tendency to fall than to rise, or to move laterally.

WHY, when a plumb-line is dropped from the declivity of a mountain, does the weight not fall perpendicular to the earth (which according to the principle of attractive gravitation it ought to do), but incline a little towards the mountain?—BECAUSE the lateral or sideways attraction of the mountain interferes with the perpendicular attraction of the earth, and the weight is nearer to the side of the mountain than to the centre of the earth.

WHY is not the convergence of the two scales of a pair of

scales from perpendicularity observable, but that they appear to be perfectly parallel to each other?—BECAUSE their inclination or convergence from perpendicularity and parallelism bears too small a proportion to the convexity of the earth to render their convergence perceptible to the senses.

WHY do projectiles, that is, bodies projected by impulsive force, as stones thrown by the hand, balls projected from cannons, firearms, &c. pursue a curvilinear or bent line in their motion?—BECAUSE they are attracted to the earth by the force of gravitation.

WHY do bodies, both great and small, thrown in a horizontal direction to the same height, reach the surface of the earth in the same time, though they have been projected to different distances and with different velocities?—BECAUSE they are attracted by the same force of gravity. It is for this cause that balls fired from two guns from the same spot, and at the same instant, reach the earth at different distances; and that a ball dropped perpendicularly from the top of a high tower, and a ball shot from the same height to the distance of a mile or two in a horizontal direction, reach the ground at the same time.

WHY are projectiles thrown from heights accelerated in their course or flight to the ground and have a wider range in their course; but when thrown from a tower, are they retarded in their course, and do not reach so far?—BECAUSE in the first case they are aided by gravity; in the second, they are retarded by it.

WHY do projectiles thrown from different heights describe different widths of curve?—BECAUSE their curvilinear motion is proportional to the impressed force.

WHAT occasions circular objects, as balls, marbles, &c. when projected by an impulsive force, to stop?—1st. THE attraction

of gravitation; 2dly, the resistance of the air; and 3dly, the resistance they meet with from friction.

WHY do circular bodies, as the wheels of coaches, carts, &c. roll easier than any other form?—BECAUSE their base is but a point, and their form diminishes the resistance of friction.

WHY do circular bodies, as wheels, balls, marbles, &c., when projected by an impulsive force on ice and a gravel path, run further on the former than the latter substance?—BECAUSE they meet fewer obstacles from the friction; or in other words, the rubbing or friction is less on the ice than on the gravel path.

WHY does a ball or other circular body remain at rest when placed on the ground or a horizontal plane?—BECAUSE the line of direction from its centre of gravity falls perpendicularly downwards to the point on which it is in contact with the earth, and therefore it remains at rest on a point of its surface.

WHY does a ball, when placed on an inclined plane, roll until it finds a level spot?—BECAUSE the line of direction from its centre of gravity falls perpendicularly downwards in front of the point on the surface which touches the plane.

*** The centre of gravity or inertia is the point where, or about which, a body balances itself, or remains in a state of rest, or equilibrium, in every position.

WHY do houses, monumental edifices, spires, obelisks, piles of timber, or other kinds of goods in heaps, coaches, carts, or other vehicles, when swayed or jolted to one side, sometimes fall down or are overturned?—BECAUSE the line of direction from the centre of gravity does not fall within the base.

WHY is the motion of a billiard ball, when struck in a direct manner by another ball, immediately arrested and its velocity imparted to that ball?—BECAUSE the action which imparted the motion to the second ball was equal to the reaction which

was destroyed in the first ball; the expanding and exerting force of both balls contributing to produce the effect.

WHY, when vehicles, as coaches, carts, boats, &c., are too high loaded, or when persons stand up in carriages or boats in motion, are they overturned or upset?—BECAUSE the centre of gravity is too much raised or elevated, and consequently, the base being narrowed, the line of direction more readily passes without the base, and thus the stability of the vehicle or boat is diminished.

WHAT supports those bodies whose line of direction falls beyond their base?—THE cohesion of their parts, arising either from their natural structure, or produced by cement or other means. The tendency also of all leaning bodies (whether at rest or in motion) to fall is partially counteracted by the centrifugal force, which acts as a counterpoise to their weight, especially in the case of bodies moving rapidly and smoothly. It is in conformity to this principle of mechanical science, that skaters in making their curvilinear turns on the ice,—that equestrians performing feats of horsemanship,—and that pedestrians and persons on horseback rapidly turning a corner, adopt the posture of leaning or inclining their bodies inwards. Dumb animals instinctively adopt the mechanical principle. It is for this cause that the leaning towers of Pisa and Bologna, in Italy—the tower for the bells of St. Mary Zobenica, at Venice—and those of Caerphelly Castle, Glamorganshire—Bridgnorth, Corfe Castle—the Monument, near London-bridge—the spire of Salisbury Cathedral, and other similar erections, do not fall, though their inclination from a perpendicular is considerable, because the line of direction from their centre of gravity falls within their base, that is, their parts which are supported by their bases have a greater tendency to keep them

from falling than the parts unsupported by the base have to incline or pull them down: thus, the centre of gravity being supported by the base, balances the body of the building, and prevents its falling. For the same reason, the human body is thrown forwards in running, or when quickly turning a corner inclines inward; that a person carrying a load leans forward; or if on the right shoulder, inclines to the left; that a nurse carrying a child leans backward; that a person ascending stairs or steps leans forward; that very fat people usually throw back their heads and shoulders; each of these actions being performed to keep the centre of gravity of the body over the base. A remarkable instance of the restoration of the walls of a building declining from a perpendicular direction has been displayed in the restitution of those of the Abbey of St. Martin's, now the Conservatory of Arts and Trade at Paris.

WHY are carriages of all sorts, as coaches, chaises, carts, and waggons, sometimes overturned in rapidly passing or turning a corner, especially when filled with passengers, or laden with goods; whereas horsemen, pedestrians, and animals escape such accidents under the like circumstances?—BECAUSE, it being the property of centrifugal force to throw all bodies from the centre, or in other words, all bodies in a state of rapid motion having a strong tendency to fly off the centre of their motion, by moving in a curve, carriages, on account of the inertia of matter, not being capable of partaking of voluntary motion, cannot produce the inclination of their bodies inwards or towards the corner, to resist the centrifugal force impelled upon them from the corner (which forms the arc of a circle), as horsemen, pedestrians, and animals do, by the inclination of their bodies towards the corner, for the purpose of counteracting by their weight the effect of the centrifugal force which

would throw them away from the corner; and therefore, not being able to make compensation for the disturbing force which is called into existence, by the gradual change of direction of the motion from a straight line to a curve, they are overturned, falling outwards, or from the corner, as soon as their centre of gravity falls without their base; or in other words, the upper part of the carriage is drawn by the centrifugal force from the corner or the centre of the arc, while the wheels are attached by gravity to the ground. Over-freighted boats and ships are sometimes upset from the same cause, by a sudden lurch, throwing the weight of the lading or cargo on one side. Incautiously rising in a boat or carriage, also, often occasions the one to be swamped or upset, and the other to be overturned, by inclining them too much to one side. For the same reason that horsemen, &c. lean much inwards when rapidly turning a corner, do skaters lean inwards when turning, and that persons performing feats of horsemanship in amphitheatres incline inwards. And the quicker the speed in turning the corner or running round the circle, the greater must be the degree of leaning inwards, for the more powerful is the tendency to fly off in a straight line.

WHY does liquid poured from a vessel which has not a projecting lip, run down along the inclined outside of the vessel? —BECAUSE on account of the attraction between the vessel and the liquid.

WHY, when a person jumps upon the ground from a carriage or other vehicle in motion, does he receive a shock, and unavoidably fall prostrate?—BECAUSE his motal inertia having been destroyed by the shock received in his descent upon the ground, the motion of his feet when they reach the ground is arrested, while his body partaking of the velocity of the vehicle

continues its motion or forward velocity. It is for the same reason that a person standing in a vehicle or boat suddenly put into motion falls backward; or that, if the vehicle or boat being in motion be suddenly stopped, he falls forwards; his body in the first case obeying the law of inertia, (or as it is figuratively termed, the inactivity or obstinacy of matter not accompanying the motion of the vehicle,) remains where it was; and in the second case, his body, having acquired the same motion as the vehicle or boat by which it was borne along, has a tendency to move forwards in obedience to the momentum or motive force imparted to it by the motion of the vehicle or boat. Or, in convertible language, the reason in the first-mentioned case is, that the inertia of matter (that is, the property of remaining stationary in whatever circumstances it may be placed) being perfectly passive in whatever situation it may be placed, whether of rest or motion, the body of the party standing in the vehicle or boat, obeying the law of inertia, remains where it was, while his feet partaking of the motion of the vehicle or boat, are drawn forwards, and consequently he falls backwards; and in the second case, his body has a tendency to move forwards in obedience to the momentum or motive force imparted to it by the motion of the vehicle or boat, having acquired the same motion as the vehicle or boat by which it was borne along; consequently he falls forward, his feet not having partaken of the impulsive motion imparted to his body. It is for the same reason, that if a horse standing quietly with its rider starts suddenly forwards, the rider is subject to fall backwards; and that while in rapid motion, if he stops suddenly, his rider is liable to fall forwards.

WHY, then, if a passenger leaps from one carriage in motion into another carriage passing it, does he not feel any shock, and sustain no fall?—BECAUSE the carriage upon which the party has leaped is possessed of the same condition as his body had derived from the carriage from which he had leaped; it being a fundamental principle of mechanics, that bodies moving in connected masses have a mutual participation of motion. It is for this reason that an equestrian leaping over a garter, jumping from the back of the horse through a hoop, or throwing balls, however high or in whatever direction, so that they slant inwards in the line of direction of his body and that of the horse,—in the first case alights upon the back of the horse, and in the second case catches the balls while he continues his course round the ring.

WHY does a spire or obelisk stand more securely upon the earth than a pillar or any oblong object will upon a waggon in motion?—BECAUSE the motion of the earth is uniform and equable, whereas that of the waggon is subject to be interrupted by the inequalities of the road. Were the present rotation, as Dr. Arnott has graphically said, to be interrupted but for a moment, imperial London, with its thousand spires and turrets, would be swept from its valley towards the eastern ocean, just as loose snow is swept away by a gust of wind.

WHAT is the cause that a person can leap from a chair without incurring danger, but if he jumps from the house-top his life is endangered?—BECAUSE the velocity or rapidity of falling bodies is accelerated or increased in proportion to the height from which they fall; receiving increased accessions, in arithmetical proportion, to their velocity, during every successive second.

WHY does the running foul of ships at sea occasion their damage or sinking?—BECAUSE when two bodies moving in opposite directions come into collision, each sustains a shock as great as if, being at rest, it had been struck by the other, with the united force or momentum of them both.

WHY can a small ship sailing in company with a large ship keep pace with or sail as fast as the large one?—BECAUSE the surface of canvas or sail which they spread to catch the effect of the wind is proportioned to the difference of resistance which the water presents to them.

WHY, if a ball of soft clay or wax be dropped from any given height, on a solid pavement, will it give way to the pressure of the pavement, and become dented or flattened on the side on which it rests; while a ball of ivory, metal, or box-wood of equal weight will rebound from the pavement with a force proportioned to the height from which it fell?—BECAUSE the ball of soft clay or wax is inelastic, but that of ivory, metal, or box-wood is highly elastic, its resiliency being occasioned by its surface giving way to the pressure of the pavement.

WHY, then, as ivory, metallic, box-wood, &c. balls are elastic, is not the mark or indent made by the concussion on their surfaces visible?—BECAUSE their elasticity, enabling them instantaneously to resume their former shape, obliterates it.

How is it known that such bodies are elastic?—BY placing a small spot of ink or other coloured fluid upon that part of the ball that is intended to come into contact with the pavement; that spot will be found to have become enlarged by the impression.

WHY do heavy bodies, as wood, stone, &c. fall, and light bodies, as feathers, balloons, &c., float in the air?—BECAUSE heavy bodies are of greater weight, and light bodies of a less

weight than equal bulks of air; and therefore the latter meet with greater resistance from the air than the former. It is on account of the absence of the resisting medium of the air, and therefore nothing conducing to counteract their tendency to gravitation, that bodies fall more rapidly in the exhausted receiver of an air-pump than they do in the open air, and that light and heavy bodies fall in it with equal velocity.

WHY do bodies of equal size but different weights, or of unequal sizes but equal weights, reach the earth in their descent at different times?—BECAUSE the resistance of the air to their descent is in proportion to the number of solid atoms which they contain, and to the comparative sizes of the bodies. Thus, a ball of lead of the diameter of an inch will reach the earth quicker than a ball of cotton of the same diameter, because it contains a greater number of solid atoms. For the same reason a bit of lead falls to the ground sooner than a feather.

WHY does a ball dropped from a height fall with greater velocity the nearer it approaches the ground?—BECAUSE, owing to the inertia of matter, any force continuing to act on a mass of matter free to obey it, produces on that mass a quickening or accelerated motion, namely, four times as much in the second instant that it did in the first instant; the velocity increasing according to the squares of the time. Thus, if a body falls a foot in the first second, it will fall four feet in half a second, sixteen feet in one second, sixty-four feet in two seconds, and so on.

WHY is a small weight descending a long way in a given length of time equal in effect to a great weight descending a proportionally shorter way in the same space of time?—BECAUSE its momentum (or quantity of motion) and force have been increased by its proportional extent of descent.

WHY does a solid ball of gold fall more quickly to the earth than the same quantity of gold will when beat out into thin leaf? —BECAUSE, being more ponderous than when increased in surface, the resistance of the atmosphere less impedes the descent.

How is the difference of lightness and heaviness occasioned in bodies?—BECAUSE the pores or openings which separate their particles are more numerous in the one than in the other. Thus, in a cubic foot of wood, the openings or pores which separate its particles are much more multiplied than in a piece of iron of the same dimensions.

WHY does a pound vary in weight in different parts of the globe, being less in Britain than on the Coast of Guinea, and more than a pound weight in Greenland; and why are weights lighter on the tops of mountains than in valleys, or in depths than on the surface of the earth?—BECAUSE weight is only the result of attraction, and is at its maximum and minimum, (*i. e.* in its greatest and least extents) at the equator and the poles, proportionally decreasing and increasing as climates are situated in respect of those two parts of the globe; these results being occasioned by the circumstance, that the surface of the earth at the poles is thirteen miles nearer the centre than the surface at the equator is, and therefore the attraction is stronger at the former than at the latter. A ball of iron weighing a thousand pounds at the level of the sea loses two pounds of its weight at the summit of a mountain four miles in height. Were the same body removed from Edinburgh to the North Pole, its weight would be increased three pounds; but if to the Equator, it would sustain a loss of four pounds and a quarter. Were it possible to be placed at the centre of the earth, its weight would be imperceptible.

WHY does the weight of bodies become less when carried

above or placed below the earth ?—BECAUSE the principle of universal gravitation or attraction decreases in intensity as the body recedes from the surface of the earth, until it reaches the centre of the earth, where it has no weight, because the attractive power is equal on all sides. This is evident from the following fact:—As a descent of a few hundred feet is found to make a sensible difference in the weight of bodies, could the descent be made to the centre of the earth, it would be found that things would have no weight there. By astronomical tests it has also been proved, that the weight of bodies is sensibly diminished in their removal upwards above the earth. At the tops of mountains the weight of bodies is less than in the plain according to their elevative proportionality or at their base; and at the distance of the moon, the weight or gravitation towards the earth of a body of 1000 lbs. weight would be diminished to five ounces.

WHY cannot the motion and progress of a stone thrown into the air be perceived until it has reached a certain height, and why in its descent does its progress rapidly increase until it reaches the ground ?—BECAUSE a body projected into the air loses velocity every moment of its ascent being diminished by the force of gravity; but a falling body acquires additional velocity every moment of its descent, being accelerated by the force of gravity. It is for this reason that a body projected into the air falls quicker than it rose.

WHY, in taking aim from the ground at a bird on the wing, does the marksman move his gun till he fires?—BECAUSE as the shot fired from a gun without motion would be destitute of motal inertia, the shots would, in all probability, if the gun was not put into motion, pass beyond or behind the bird; but by the movement of the gun in the direction of the bird's

flight, and at its rate of flight, the shots partake of the lateral motion given to the gun, as also of the direction of the bird's flight.

WHY will a cannon or musket ball discharged horizontally reach the ground of a level plane equally soon as another ball dropped by the hand at the moment of the discharge from the mouth of the cannon reaches the ground, though the first ball, if pointed only quite horizontally, has been carried 600 or 800 feet, and the space traversed by the second ball is but two or three feet from the cannon's mouth to the ground?—BECAUSE forward or projectile motion does not in the slightest degree interfere with the action of gravity.

WHY will a bullet, a pellet of clay, a tallow candle, a little tallow, or a small bag of water discharged against a door hanging freely on its hinges, perforate it without producing the least agitation in it?—BECAUSE the impression of the stroke is confined to an isolated portion of the door, and sufficient time does not occur in the action of the discharged substance on the door for diffusing its influence over the extent of the door.

WHY are such soft bodies as candle, clay, &c. able to penetrate a board when discharged from a gun?—BECAUSE the momentum or force of a shot is not the sole effect either of its weight or of its velocity, but the product of both. A light or a soft body propelled with velocity has, therefore, an effect equal to that of a heavy or a hard body propelled with less velocity.

WHY does the recoil of a gun hurt the shoulder if the gun is not held close to the shoulder?—BECAUSE the gun recoils with the equal momentum or motion that the powder has imparted to the ball. The reason it does not recoil when held close to the shoulder is, that the momentum imparted by the

discharge has been diffused through the mass of the gun, and therefore the velocity of the recoil is small and scarcely perceptible.

WHY does a sky-rocket ascend?—BECAUSE after it is lighted its lower part is continually producing a large quantity of aëriform fluid, which in expanding presses not only on the air below, but also on the rocket above, and thus lifts it. The ascent is aided also by the recoil of the rocket from the part of its substance, which is continually being shot downwards.

WHY is a cricket-ball, when struck fairly by the bat, impelled to a considerable distance, but when struck sidewise, but to a comparatively short distance?—BECAUSE in the first case it is struck in the centre of action or percussion, that is, in the centre of the inertia of action and reaction; but in the second case it is struck at or below the central part of the bat.

WHY is a blow given to a nail by a poker not so efficient as that by a hammer?—BECAUSE its centre of action is not at its extreme point, as is the case with the head of the hammer.

WHY is a piece of bar iron made red hot by hammering?—BECAUSE the metal is thereby compressed; it being the property of air, when violently or forcibly compressed, to ignite substances.

WHY are certain metals, as gold, &c. malleable, while others are too brittle to be so reduced?—BECAUSE their atoms cohere equally in whatever relative condition they may be placed, and therefore yield to force, and shift about among one another, in a manner similar to the atoms of fluids.

WHY can some time-pieces go for eight days, or even a year or any intermediate time, without being wound up?—BECAUSE the number of wheels on which their movement depends is proportionably increased according to the time re-

quired for their going without being wound up. If a material could be produced sufficiently durable, the movement, without winding, might be made to proceed for a hundred or a thousand years, or any indefinite period of time.

WHY can no power of extension make straight or overcome the disposition of flexible cords or chains to bend down in the centre or middle?—BECAUSE of the weight or gravity of the materials.

WHY are chains stronger and more advantageously employed than cables in maritime affairs?—BECAUSE the chain, by its weight, hangs as a curve or an inverted arch in the water, but the rope, being nearly the weight of the water, is supported by it, and becomes almost a straight line between the anchor and the ship. Therefore, when a great wave dashes against the ship, the straight rope, yielding only by elasticity of its material, gives way comparatively but in a small degree; but the bent chain, yielding until it is drawn nearly straight, is enabled to stand a greater shock by its greater capacity of yielding and its consequent duration of resistance.

WHY is hempen rope preferable to iron chain for the scale of a weighing machine?—BECAUSE the rope resisting a greater weight falling into the scale than the chain can, the hemp yielding by its elasticity, and continuing its resistance through a considerable space and during a considerable time, it gradually overcomes the momentum, but the iron chain not yielding, must be of a strength sufficient to stop the mass suddenly to prevent its breaking; and thus its inconvenient weight and size render it less advantageous for use than hempen rope.

WHY by twisting ropes or cables is their power of tension and resistance increased?—BECAUSE the twisting or intertwining of the hanks imparts an additional power of tension and

resistance to each individual hank to that which it possessed in a longitudinal state.

WHY by alternately splicing together long and short pieces of a mast or beam, sawn lengthwise, and overlapping them with a rope, is the mast or beam rendered stronger than it was before it was fractured?—BECAUSE the weaker part on one side is supported by the stronger part on the other.

WHAT is the benefit resulting from making the surfaces of railroads as smooth and level as possible?—THE greater attraction of cohesion between the engine and train and the rail, and consequently the less probability of the former being thrown off the latter.

WHY does the giving of a high degree of velocity in steam navigation require more than a proportional expense of fuel?—BECAUSE the resistance of the water increases as the square of the speed.

WHY are air expansion engines considerably more powerful than steam engines?—BECAUSE heat, when employed to dilate air, produces a quadruple expansive power that it does in the formation of steam.

WHY does not the generator, when cracked by excessive heat, immediately allow the escape of the vapour or water?—BECAUSE the vapour or water is repelled by the repulsive power of the heated metal to a distance from the metal, and thus virtually stops the crack until the temperature is allowed to fall.

WHY is not high pressure (or condensed) steam issuing from a boiler heated to 300° better than that of low pressure steam issuing from a boiler at 212° of heat?—BECAUSE at the instant that the high pressure steam issues into the air, it expands until balanced by the pressure of the atmosphere, and is consequently cooled by the expansion.

WHY is steam more advantageous for heating rooms and houses than coal fires are?—BECAUSE, besides its economy, it requiring not a moiety of the expense for coals or other fuel for its production, it can be made to produce any degree of temperature required, and will not only heat the room in which it is produced, but the adjoining rooms and even the whole building, and is conducive to health, cleanliness, and comfort, as it promotes the ventilation of a house, and is free from the dust and noxious odours generated by coal or wood fires.

SINCE strength of materials is increased by adding bulk to them, as by increasing the breadth and depth of a beam its strength is increased in proportion to the number of fibres or resisting particles added; why does experience demonstrate that there is a natural limit to the magnitude of all structural and mechanical arrangements, and that they cannot be carried beyond a certain extent, so as to ensure their stability?—BECAUSE in increasing the dimensions of a body, or of a combination of bodies, the weight increases more rapidly than the increase of strength or power of endurance.

WHY is a piece of wood in the form of a beam less liable to bend or break than the same quantity of wood in the form of a plank, whether placed longitudinally or in a sloping direction?—BECAUSE the resisting lever is smaller in proportion as the beam is thinner. It is for this reason that the roofs of all buildings are supported by rafters instead of employing the same quantity of material in the form of planks.

WHY is a beam when bent by weight or pressure in the middle liable to break?—BECAUSE on the upper surface the destroying force acts by the long lever, extending from the end of the beam to the centre, and the resisting force or strength acts only by the short lever, extending from the side to the centre,

while on the under side only a small proportion of the substance of the beam is capable of affording an opposing resistance.

WHY is the arch, whether circular or elliptical, the strongest structural form?—BECAUSE the particles of the arched body bear upon one another like wedges; thus causing a compression of particles in the concave side of the circle, which gives to the convex side compression and power of resistance in proportion to the pressure perpendicular to the convexity. It is for this reason that the strength of beams of wood, and all fibrous or grained materials, when placed in an oblique or a leaning position, as in the angular roofs of houses and other buildings, or in the construction of arches, is greater than when placed longitudinally. It is also for the same reason, namely, its adaptation to bear pressure, that the domes of churches, cathedrals, &c., resemble the arch; that vessels for evaporating and distilling in vacuo are made of an arched form in order to enable them to bear the external atmospheric pressure when empty; and that bottles from the arched form of their upper parts bear the superincumbent weight of the water when lowered in the sea.

WHY is a hollow tube of metal stronger than a solid rod consisting of the same quantity of metal?—BECAUSE the substance of which it is composed extending to a greater distance from the centre than that of the solid rod, resists with a larger lever. In accordance with this principle pillars of cast iron for the support of buildings, masts, and yards of ships are made hollow.

WHY are ships and boats made after the model of water-fowl and fish, which partake of the shape of the wedge?—To enable them to encounter the resistance of the water. Their stern or hinder parts being made of a narrow tapering form is to allow the displaced fluid to disperse itself freely, in order that their passage through the water may not be impeded.

WHY does the hare when pursued by the greyhound run in a zigzag direction?—BECAUSE by doubling, that is, by changing the direction of its course, and turning back at an acute or oblique angle with the direction at which it had been running, the greyhound, which is unable to make the turns so rapidly, is impelled, by the tendency of its comparatively heavy body, to persevere in the rapid motion which it had acquired in the pursuit, a considerable distance forward before it can check its speed and return to the pursuit, and thus the hare, which is much less fleet than the greyhound, is enabled by this scientific manœuvre to shoot far ahead of the greyhound in the other direction.

WHY is a man lying in a recumbent position, and upon whose breast an anvil is placed, enabled to bear violent blows made with a sledge-hammer on the anvil, without injury or even any unpleasant sensation; and why does he perceive a less sensible shock from blows made upon freestone than he does when made upon the anvil?—BECAUSE in the first case the vis inertiæ of matter, or the reaction of the anvil, is his security; and in the second the reaction of inelastic bodies is greater than that of elastic bodies.

How are those vast exhibitions of human strength which are sometimes displayed, accomplished?—BY the position in which the exhibitor places himself, so as to render his body elastic. For this purpose he places his body with his shoulders resting on one chair, and his feet upon another, both being so fixed as to yield a firm support; the backbone, thighs, and legs, thus forming an arch or curved position, of which the chairs are the abutments. It was thus that Firmius, one of the Roman tyrants, was able to bear an anvil on his breast while others were hammering on it; and that Eckeberg, mentioned in Beckman's History of Inventions, could bear large

stones to be broken on his breast, or a smith to forge iron on an anvil placed upon it. Similar feats of conjurors of the present day are performed on the same principle.

How are the feats of dexterity of dancing on the tight rope, of standing or walking on the slack wire, of balancing bodies in motion or at rest, of walking on stilts, &c. accomplished?—By maintaining the state of unstable equilibrium by keeping the whole of the body and the articles exhibited accurately balanced or equipoised either by the extension of the arms, or by holding a long pole, with weights at each end, in a transverse direction or across the rope, at the same time fixing their eyes on some object parallel to the rope, bywhich means the exhibitors are enabled to ascertain when their centre of gravity delines to one side of the rope or to the other, and thus to maintain the centre of gravity over the base of the rope. It is in conformity with the same principle, that a man carrying a burthen, or a person going upstairs, leans forward, or that if we slip or stumble we extend the arm opposite to the foot that has failed.

Why is it not easy for four-footed animals to stand on their hind legs?—Because their centre of gravity lies too far forwards when they are in that position.

Why do cats always alight on their feet in falling?—Because when springing or dropping from a height they hang down the fore and hind feet and tail so as to bring the centre of gravity or line of direction to a point below their breast, which descending first makes them fall as they do. It is by the same means that all animals that spring upon their prey uniformly spring upon their feet, and that the chamois and wild goat make their fearful and terrific leaps among the Alpine precipices without danger.

Why do persons walking together arm in arm strike each

other unless the steps of their right and left feet correspond? —Because the centre of gravity in each body falls in the action of walking alternately over the right and over the left foot of each person.

Why is sea-sickness produced on ship-board?—Because, besides the irregular pressure of the bowels among themselves produced by the rising and falling of the ship, and against their containing parts, their inertia or downward pressure varies according to the motions of the vessel. Man, strictly to maintain his perpendicularity, or keep his centre of gravity over the support of his body, requires standards of comparison, which he obtains chiefly by the perpendicularity or known position of objects around on land; but on shipboard, where the lines of the masts, cables, windows, furniture, &c. are constantly changing, his standards of comparison are soon lost or disturbed, and the consequence is his animal economy partakes of the disturbance, and feeling oppressed with all foreign substances or his ingesta, relieves himself from them by vomiting. The same effect is produced by looking at the restless motion of the waves. The reason that sea-sickness may be obviated by looking on the sea-shore or by lying on the back with the eyes shut, is that the motions of the vessel are not seen.

What occasioned the fall of the Broughton Suspension Bridge over the river Irwell, near Manchester, while the 60th Rifles were marching over it, April 12th, 1832?—The powerful vibration communicated to the structure by the measured and simultaneous uniform step of the men, which, causing the weight of the bridge by the repeated vibrations or agitations to act with successive jerks on the main chains, had a more powerful effect on them than a dead weight of much larger amount than that of the whole of the men would have had.

WHY, in raising water in a bucket out of a well, or any other weight from a depth, by means of a wheel and axle, is the difficulty increased, and the weight appear greater, as every additional coil of the rope is made on the axis; but that in raising the same by means of a rope and the hand, the difficulty and the weight should be diminished, as the object ascends nearer the top of the well, or that of the depth?—BECAUSE in the first case the proportional difference between the circumference of the wheel and the axle is continually diminished, and in the second case it is increased.

WHY is animal power not exhausted so much in proportion to the intensity of force exerted as in proportion to the time during which it is acting?—BECAUSE exhaustion is, *cæteris paribus*, in proportion to the time during which the muscles are in action; for though the quick mover exerts more force during the time he has to bear the exhaustion, his exertion is called into action for a considerably less period of time than that of the slower mover, a less time having occurred for the retarding force to operate. Thus, if a stage-horse is driven up an ascent in one minute, while another horse is allowed four minutes to perform the same distance, he has of course to bear his load only one fourth of the time of the slow mover, and must consequently be exhausted only in that proportion, allowing for the greater exertion required for his increased velocity.

WHY do horses exert their power better by themselves than when yoked with others?—BECAUSE of their incapability of making the same exertion, or having the same spirit and motion.

WHY are the powers of the horse better adapted for draught than carriage?—BECAUSE of the formation of his body.

WHY is he capable of exerting a greater power of draught on a level road than going up hill?—BECAUSE in proportion

as a hill or road rises one foot in twenty, the horse is compelled, besides overcoming the friction or other resistance which the carriage meets from the hill or road, to lift one twentieth part of the weight of the load.

WHEN is his strength exerted to the greatest advantage?—WHEN he can throw his centre of gravity forward as a make-weight. It is by the same contrivance that the Albanian porters at Constantinople are enabled to carry the enormous weight of eight or nine hundred pounds on their backs by stooping forwards, and assisting their steps by a short staff.

WHY does the sloping line of traction direct from the shoulders of the horse to the load enable him to exert his power to the greatest advantage, and to draw the greatest weight?—BECAUSE it tends to raise the load from the ground, thereby lessening the amount of friction.

WHY, as the seat of resistance is posited, as if the load be placed too high or at too great a distance from the horse, is his power impeded or diminished?—BECAUSE if placed too high or at too great a distance, the weight he is required to draw will be increased; if too low, part of his power will be uselessly expended in lifting the weight.

WHY do drivers of carts on ascending hills or steep roads cause their horses to take a winding or zigzag course, instead of driving them in a straight line of direction?—To ease the pull and save labour to their horses, the load being thus gradually supported by the zigzag course. For this purpose roads of very steep hills are made to wind or zigzag.

WHY is the greater weight of the load of a waggon, cart, &c., placed on the hinder wheels?—BECAUSE the power necessary to overcome any obstacles which may occur on the road is diminished by the increased diameter of the wheel; the larger the

circumference of the wheel being, the more easily are obstacles, such as stones and inequalities on the road, overcome.

WHY are wheeled carriages preferable to sledges for traction? —BECAUSE as in the course of one mile the axle and bush of wheeled carriages glide over only about thirty yards of a smooth oiled surface in a gentle waving line, the resistance of the friction of the road and carriage is reduced to 1-100th of what it is for a sledge.

WHY are axles made of steel and the bush of brass?—BECAUSE when substances of dissimilar kinds rub against each other the friction is diminished.

WHY are springs of use to carriages?—BECAUSE they not only render their motion easy and diminish the pull to the horses, but they convert all percussion into mere increase of pressure. Without springs the whole weight of the carriage and its contents rise with the inequalities of the road and sink with its depressions; whereas in spring carriages moving rapidly along, only the parts below the springs are moved, in correspondence with the irregularities, while all above by the inertia of the matter have an easy and equable advance. The advantage of under-springs is, that all the parts of the carriage, except the wheels and axle-tree, are insulated from the effects of shocks. When only the body of the carriage is on springs, while all the heavy frame-work below it is subject to the effects of the irregularity of the road, the difficulty of traction is consequently increased.

WHY are wheels made of a "dished" form, that is, inclining outwards?—BECAUSE by that form they partially partake of the strength and properties of the arch. An additional advantage of the "dished" form is, that when the carriage is on an inclined road, and consequently more of the weight

falls on the wheel of the lower side, the inferior spokes of that wheel become nearly perpendicular, and therefore support the increased weight more securely.

WHY are the wheels of carriages, waggons, carts, &c., when heavily laden, dragged, locked, or shoed, when going down steep hills or places?—To prevent them from slipping, by imparting to the wheels an increased or a continued friction, and thus diminishing the velocity of their descent.

WHY does oil or grease lessen the friction of wheels, locks, hinges, &c.?—BECAUSE it fills up the cavities of the surfaces which come into contact in the motion, and thus removing their asperities, causes them to slide the more easily over one another.

WHY is great force necessary at first to set a vehicle in motion, and a strong effort requisite before it can be stopped?—BECAUSE of the law of inertia or inactivity in the body and of the momentum or motal force.

WHY is the friction between pieces of the same substance with similar grains greater than between pieces of different substances with dissimilar grains?—BECAUSE of the roughnesses of the grains or little asperities and projections mutually fitting one another.

WHY does the friction of various woods and metals against each other vary?—BECAUSE of their different degrees of hardness; soft woods and metals, exhibiting more resistance than the hard varieties, present a greater friction.

WHY is the friction of substances reduced when it has been continued a certain time?—BECAUSE the minute asperities and projections of the surfaces in contact have been reduced by the friction, and the surfaces have consequently become smooth.

WHY does a razor if drawn lightly over the hand make an incision in the flesh, but if pressed against the hand with considerable force make no incision?—BECAUSE of the vibration of the particles produced by the drawing action, which enables the razor to insinuate itself into the flesh.

WHY is friction of use?—BECAUSE, independent of its uses in the arts, it secures the stability of all bodies and substances. Were it not for friction, men and animals walking upon the ground or pavement would be as if walking upon ice; and rivers which now flow calmly would be frightful torrents. So wise and provident are all the provisions of Nature!

WHY have concave mirrors the same effect as burning glasses, and why will they fuse metals as effectually as fire?—BECAUSE they collect the sun's rays from the whole of their surface into a focus. By their power a piece of tin has been melted in three seconds, and of copper in sixteen seconds. The last mentioned metal has been liquified in thirty-four seconds at the distance of 50 feet, and at 120 lead and tin have been melted. Buffon liquified silver by their action, and at 250 feet set beech-wood on fire. By the effect of transmission of radiant heat by the combination of 168 small plain mirrors, so placed that they all formed a concave mirror, and reflected radiant heat to the same focus, Archimedes consumed the ships of the Romans during the siege of Syracuse, and Proclus destroyed the fleet of Vitelianus before Constantinople. It is on account of the same cause that semicircular polished tin meat-screens, independently of their protecting the meat from the currents of air, more expeditiously dress the joint than flat tinned screens.

WHY do two bodies, as two pieces of wood or marble, when rubbed together, adhere?—BECAUSE the air is expelled from between them, and the external air pressing upon them in all

directions, both laterally and perpendicularly, keeps them united. It is for the same reason that two hemispheres forming a hollow sphere, when exhausted of air, cannot be easily separated; that two portions of the same size cut from two leaden bullets, when the fresh surfaces are brought into contact, cohere by virtue of cohesive attraction; that a string and a piece of wet leather closely attached to a stone will raise the stone; and that it is difficult to raise a vessel from the ground that has been exhausted of air.

WHY do some bodies, as metals (namely, iron, &c.,) adhere together with greater force and require greater force to separate their parts, than others (namely, fluids, as waters, &c.,) do?—BECAUSE dense bodies contain a greater number of atoms than porous or soft bodies; the principle of their attractive cohesion is therefore proportionately greater.

WHAT has preserved the pyramids or monumental structures of Egypt from destruction, and in their original state of freshness and perfection?—THEIR preservation has depended on the peculiarity of their form, which is the best of all other formations of structure to resist the force of gravitation, and the serene dryness of the atmosphere of Egypt has tended to preserve them in their present state of freshness and perfection.

*** See also on the properties of Mechanical Science the last nine problems of HYDROSTATICS.

OPTICS.

OPTICS (ὀπτικη, from ὀπτομαι, to see) is the science by which we investigate the properties and phenomena of light and vision, and distributes itself into two parts; CATOPTRICS (κατοπτρον, a mirror), which relates to the reflection of light and the various phenomena that depend on it, and DIOPTRICS (διοπτομαι, to see through), which relates to the refraction of light and the various phenomena that result from it.

How is vision produced, that is, how are objects rendered perceptible to our organs of vision?—BY the rays of the light of the sun, or of any other source of light, being reflected from the object so as to fall on the retina or back part of the eye, and there forming an image or resemblance of the object. This is proved by the circumstance of persons or objects that are around a fire in the open air at night being visible to a beholder at a distance, while the person of the beholder is not visible to them, he not being within the range of the light, so as to cause it to be reflected from him.

WHY do objects at a distance appear less than they really are, and smaller according to the increase of the distance?—BECAUSE of the diminution of the visual angle at which they are viewed, that is, they present themselves to the vision of the beholder at a smaller or more acute angle than they do when viewed at a nearer distance. This is the reason that the heavenly bodies appear so small, that the sun and moon appear of the same size, and that a sixpenny piece or other small object will hide the sun from one's view. It is for the same reason that an avenue of trees or two rows of pillars, though

of equal size and perfectly parallel, appear smaller and closer at the further extremity than they do at the near extremity, and gradually decline in size and distance from the nearer to the farther extremity. It is also because we judge of things according to the extent of the angle under which they present themselves to the eye that two or more bodies moving at different distances appear to move with different velocities.

WHY do objects of unequal size or magnitude, when situated at unequal or different distances, appear of equal size; and why do objects the real magnitudes of which are very unequal, assume an apparent equal magnitude when situated at different distances?—BECAUSE the apparent magnitude of objects depends on the angle under which they are seen, or which they make in the eye; the nearer any object is to the eye, the angle by which it appears to the eye being the larger, and therefore the greater will be the apparent magnitude of the body, and consequently its picture or image formed upon the retina, or organ of optical sensation, will be proportioned to the apparent magnitude, and *vice versâ*. Thus an object at the distance of 200 yards from the eye will make the visual or optical angle twice as small as when it is but 100 yards distant, and therefore will appear twice as small in the first position as in the second position. But the rule or principle of judging of the magnitude of objects according to the visual angle is applicable only to objects whose distance is considerable, for the size or magnitude of near objects is not judged according to the visual angle, but according to the judgment. Thus the proportional sizes of a man and a child seen at a distance of a few feet are not judged of according to the visual angle, but according to the judgment.

WHY does the picture or image of objects appear to a person

looking into the eyes of another to be inverted on the retina or bottom of the eye, though the objects are in their natural upright position?—Because the image of the object formed on the retina of the eye is reflected to another plane, the image being seen in the direction of the ray which conveys the sensation to the organ of vision, or rather in the direction of the axis of that pyramidical form, that a pencil of divergent rays forms in proceeding from any point of an object. It is for the same reason that a person looking into the hollow of the bowl of a polished spoon sees his face or bust inverted, or upside down.

Why then, if the pictures or images of objects appear invertedly upon the retina of the eye to a person when looking into the eyes of another, does the person himself perceive the objects of vision in his own eye in an erect position?—No philosophical explication can be given; the question has exercised the ingenuity of mathematicians, physiologists, and metaphysicians without avail.

Why, as the image of objects is formed on the retina of each eye, do we not see objects double?—Because the action of the rays on the optic nerve of each eye is so perfectly similar, that they produce but a single perception.

Why, when two objects are unequally distant from the eye of the spectator, and passing over parallel and equal spaces in the same time, does the most remote appear to move the most slowly, and the nearest to move the most rapidly?—Because the apparent velocity of bodies moving in parallel lines, at different distances from the eye, are distinctly as the real velocities, and reciprocally as the distances.

What produces the delusive sensation when we look at the sun, or from a vessel to the shore, or from a coach to objects on the wayside, that it is not the body from which we

are looking, but the body which is at rest that appears to be moving, and going in a direction contrary to that in which we are moving?—OUR incapacity of seeing our own motion, or that of the body in whose motion we participate. It is for this reason that two or more objects at a considerable distance, moving with velocity past a third object which is at rest, appear to a spectator to be perfectly at rest, while that which is really stationary appears to be in motion. And the rationale is, that the eye, which is fixed on the objects, follows their motion mechanically. Thus, a person in a passage-boat does not perceive its motion while sailing up or down a river, but imagines that the objects which are stationary on each bank, with the banks themselves, are in motion in a contrary direction to that in which he is sailing, or that they are retiring behind him. For the same reason, the clouds that pass over the face of the moon appear to be motionless, while the moon assumes the appearance of proceeding rapidly along in an opposite direction. And for the same reason the sun and other heavenly bodies appear to have that diurnal motion which belongs alone to the earth.

WHY is the sight of objects lost after they have proceeded a certain distance or are receded from?—BECAUSE the rays of light that emanate from them become so rarefied, on account of their divergency or tendency to extend themselves, that the pupil of the eyes is disabled from receiving a sufficient quantity of them to cause an impression upon it: for distant objects appear not only indistinct but obscure, because of the deficiency of light, many of the rays being intercepted in their passage through the air. From this cause arises the difference in the appearance of such objects in a dark, cloudy day, when the air is

impregnated with vapours, from that which they assume when the sun shines full and strong upon them.

WHY are very minute objects imperceptible to the naked eye?—BECAUSE the sense of sight is limited not only with respect to distant objects, but with respect to those that are near; in each case the objects subtending angles too small to be perceptible. The distance or limit of distinct vision to an eye in a sound state varies in persons from six to ten inches; but very near-sighted persons can see at the distance of but one or two inches, and therefore they can see minute objects distinctly which are not perceptible to long-sighted persons but by the aid of a microscope.

WHY do objects appear dim or not clear to some persons? —BECAUSE the transparent coating of the eye is dull, or the lens of the eye is too flat or too convex.

How is squinting occasioned?—BY the imperfect vision, or the inability of one eye to follow the motions of the other, which occasions the imperfect eye necessarily to look in a different direction from the other.

WHY do long-sighted persons receive greater benefit from convex lenses than that which short-sighted persons do from concave ones?—BECAUSE an object seen through a convex lens is not only magnified, but is seen brighter by the eye receiving a larger pencil of light from each visible point, on account of the rays entering it being less divergent; whereas a concave lens not only diminishes objects, but also renders them darker, because the rays of light are thus transmitted more diverging to the eye, and consequently the pupil cannot receive so many of those rays as it otherwise would.

WHY are the crystalline humours of the eyes of fish globular

and solid?—THEY are dense or solid to render the refraction of the rays of light greater, and they are spherical, in order that as small an interval as possible might be formed between the anterior surface and the bottom of the eye, that they may have a sufficient field of vision.

WHY do near-sighted persons suppose distant objects to be of a greater magnitude than persons do who are long-sighted?—BECAUSE the eyes of near-sighted persons receive on the retina all the rays of light issuing from the images of objects beyond the point of their intersection, and consequently at a point where they are more extended.

WHY can those persons, who after a certain age become presbytes, (that is, see distinctly distant objects from which the rays of light issue nearly parallel,) read print by exposing it to the rays of the sun or other strong light?—BECAUSE the intensity of light thrown upon the object, and thence transmitted to the eye, causes them to contract the pupil in an extreme degree, which thus produces the necessary convergency of the rays for rendering vision distinct.

WHY do concave glasses enable short-sighted persons to see better at a distance, and convex glasses benefit the vision of those who cannot see things that are near distinctly?—BECAUSE the cornea of the eyes of short-sighted persons being too much flattened, the concave glass or double concave lens collects, by the artificial divergency of its concavity, the pencils or rays of light emitted or reflected from objects under a more convenient angle of vision, and causing them to converge sooner than they otherwise would, presents them more distinct and concentrated to the eye than the defect of nature allows; whereas the pupil of the eyes of long-sighted persons being often too round or convex, objects present themselves to their sight under too

open angles to be distinct, the pencils or rays of light uniting in a focus before their arrival at the retina or organ of visual sensation: the convex lens or glass, therefore, removing the object to a greater distance, and causing the pencils of light reflected from it to diverge, the angle of vision is contracted, and the pencils or rays of light reflected from objects being collected and concentrated in a focus on the retina or organ of visual sensation, the image of objects is presented distinctly to the sight, by enabling the eye to form the image in its proper place.

*** The extent of vision taken in by the eye, compared with the smallness of the visual tablet, is forcibly illustrated by Dr. Paley, in his Natural Theology.

"In considering vision as achieved by means of an image formed at the bottom of the eye, we can never reflect without wonder on the smallness, yet correctness of the picture. A landscape of five or six square leagues is brought into a space of an inch diameter; yet the multitude of objects which it contains are all preserved, are all discriminated in their magnitudes, positions, figures, and colors. The prospect from Hampstead-hill is [can be] compressed into the compass of a sixpence, yet circumstantially represented. A stage-coach, travelling at its ordinary speed for half-an-hour, passes in the eye only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress; for it is only by means of that perception that the motion of the coach itself is made sensible to the eye."

WHY are some persons short-sighted? — BECAUSE the humours of the eye having shrunk or decayed through weakness or other imperfections, the cornea is too flat, and therefore the rays not being sufficiently bent or refracted, they arrive at

the retina before they are united in a focus, and consequently do not make an impression sufficiently correct and forcible, but form an indistinct picture or image on the bottom of the eye, and exhibit the object on the retina in a confused and an imperfect manner.

WHY do bodies seen from the ground appear higher than when seen from heights and elevations?—BECAUSE the visual or optical ray inclines or descends, in proportion as the eye is more elevated.

WHY do the distances, heights, and relative positions of hills, valleys, towns, and other objects often appear altered or changed, sometimes nearer and sometimes more remote than they really are?—ON account of the state or condition of the atmosphere, through which light has to pass in its passage to the earth. For this reason objects in a fog or mist become magnified or appear further distant than they really are, because the fog or mist diminishing the intensity of the light reflected from the objects makes them appear further distant without lessening the visual angles subtended by them. Thus a person in a fog may believe that he is approaching a great tree, fifty yards distant, when the next step throws him into the bush which he had supposed to be the great tree.

WHY do distant objects and mountain ranges appear nearer in damp moist weather and preceding rain than they really are, or than they do in dry weather?—BECAUSE moist air has the effect of producing a greater reflection and refraction of the rays of light than dry air has.

WHY does an object upon the summit of a hill appear more distinct than one at an equal distance in a valley or on a plain? BECAUSE, 1st, the air being more free from vapours and exhalation in an elevated situation, and the reflected rays conse-

quently brighter than in a low situation; and 2dly, as objects on elevations (as when on the summit of the hill) have a back-ground of light sky, consequently the contrast of the object and of its back-ground makes its outline more distinct.

WHY do distant hills appear nearer in sunshine than in a cloudy day?—BECAUSE their outlines are more sharply defined; the intensity of light and shade in which objects are seen diminishing according to the square of the distance; being only one-fourth as powerful at twice the distance, one-sixteenth at four times, and so on.

WHY, when we stand upon the sea-shore, do those parts of the ocean which bound the sensible horizon appear elevated on a level with the eye; or why, when standing on a horizontal plain, do the different parts of the plain appear elevated in proportion, till at length they appear on a level with the eye of the observer?—BECAUSE the globular form of the earth is not perceptible to the eye, and if it was, the apparent elevation of the sea or of the plain is far greater than the arch which a segment of the globe would form, within any distance that our eyes are capable of reaching. It is for the same reason, that the distant parts of a long wall appear to a person who stands at one end of it to curve or incline towards him. And in the same manner, a lofty tower seems to a spectator lying down on his back at a few feet distant from its base, to bend over him, and threaten him with instant destruction.

WHY when a person stands a little to the side of a looking-glass cannot he see himself, whereas if he stands directly before the glass his image is reflected back to him?—BECAUSE the rays which strike upon a plain mirror obliquely are reflected back in an opposite direction. It is for the same reason, that if a candle be placed a little to one side of a looking-glass, its

image in the glass cannot be seen but on the other side of the glass. And it is according to the similar law of mechanics, that a marble or ball thrown sideways against a wall or wainscot rebounds off at a similar angle or the same obliquity in an opposite direction.

WHY, when we approach towards a mirror or looking-glas does our reflected image seem to move with double the velocity of ourselves?—BECAUSE the velocities of the two equal and contrary motions, namely, that of ourselves and that of our reflection, are seen united on the reflection.

WHY, then, while we are standing at a mirror, does the reflected image of a person walking towards the glass appear to us to move only at the same velocity as he does in his approach, though to himself the rate of the velocity of his image seems to be double?—BECAUSE to us there is but one motion, but with regard to himself there are two equal and contrary motions.

WHY is but half the size of a person viewing himself in a looking-glass seen, however he may change his distance from the glass?—BECAUSE his image or reflection appears behind the glass exactly at the same distance as his person is before it, the mirror being half-way between the real object and its reflection, and cutting in half the cone of rays proceeding from the object to its reflection.

WHY is the image of the beholder, or of those objects which are placed near it, reflected from a looking-glass?—BECAUSE the coating of the amalgam of tinfoil and mercury placed on the back of the glass prevents the rays reflected from other objects disturbing the image produced from the reflected rays of the beholder, or of those of the objects immediately near the glass. The cause is the same, when by placing a hat, board,

or the like, on the other side of the glass of a window, the image of the beholder is reflected.

WHAT occasions the optical illusion, that objects seen by reflection in a plane mirror appear to be beyond the surface?—This problem is solved in the preceding one.

WHY are not the spectra or images of objects reflected from looking-glasses inverted as they are when viewed in the camera obscura, or on the retina of the eye, or when represented on the wall of an apartment by light admitted through an aperture in a window-shutter?—BECAUSE the rays from the eyes of the beholder do not cross each other, but fall perpendicularly, and not altering the direction of the reflected rays are reflected in the same line; and therefore the spectrum or image appears behind the glass precisely similar to the object before it.

WHAT occasions the luminous cross which appears from the reflection of a candle in a looking-glass?—IT is produced by the direction of the friction by which the glass is polished: the scratches placed in a horizontal direction exhibiting the perpendicular part of the cross, and the vertical scratches the horizontal part.

WHY, when the sun or any other strong light illuminates the inside of a round vessel, do two luminous circles appear to unite in the form of a heart near the centre or axis of the vessel?—BECAUSE luminous curves are produced by the consecutive intersection of the rays of light reflected from each of the continuous points of the concave circumference of the vessel which is enlightened.

WHY in rock crystal, Iceland spar, &c. is a double image or appearance of an object seen, when between such a crystal,

spar, &c. and the eye an object is interposed?—BECAUSE those substances possess the property of double refraction. Thus, one image is, by the ordinary refraction of light, reflected in an upright or a vertical plane, and the other by extraordinary refraction quits the plane perpendicular to the refracting surface.

How can a person see objects placed at his side, and even behind him, though he looks straightforwards?—BY the reflection in the polished surfaces of small metallic mirrors or two small pieces of silvered glass so hinged to the frame of spectacles as to stand at any angle with respect to the eye.

WHY if we look down a straight road do the pathways on each side seem to unite in the distance, and at this point, if there should be two trees, one on each side of the road, do they appear as one tree; but as we walk along the road, do the trees appear gradually to separate, and the road beyond them can be seen?—BECAUSE, according to geometric principles, objects presented in the same manner to our view appear to diminish in magnitude in proportion as they are farther from the eye; for the lineal dimensions of objects so placed are constant bases of a triangle, whose sides are the distances of their two extremities from the eye; their opposite angles consequently increase; and therefore the third angle, or that opposite to the constant side, diminishes, and forms in the eye images smaller in proportion.

WHY, when we look up an avenue of trees, do the trees appear smaller as they are more distant, and to gradually approach each other till they meet in a point?—BECAUSE as the trees and the road form a smaller visual angle, in the proportion as they are the more distant from the observer, therefore the width of the road gradually diminishes, as well as the size of the trees, till at length the road apparently terminates in a

point at which the trees seem to meet. It is for the same reason, that the floor and lateral walls of a long gallery appear to converge towards each other, and meet in a point.

WHY, when in the midst of a plain, do all objects seem to form a circle round the observer?—BECAUSE when objects are extremely distant it is impossible to form a correct judgment of their respective situations, and therefore all the points appear to be equally distant from him. It is from the same cause that an irregular line when far posited appears to be an arc of a circle, and that the firmament presents the appearance of a concave hemisphere sprinkled with stars.

WHY does a person with his back towards the moon not perceive water or other objects clearly; whereas if he faces the moon, he sees them clearly?—BECAUSE, in the first case, the light of the moon is reflected in an opposite direction; whereas in the second case it is reflected back in a direct direction.

WHY can the cat, the lion, and the lynx see in the dark?—BECAUSE the great power of the construction of their eyes enables them to collect into one focus whatever rays of light there may be existing at the time, which after having been thus concentrated are reflected in a brilliant concave mirror at the bottom of the eye.

WHY does the shadow of a hand held between a candle and the wall appear gigantic?—BECAUSE the light-giving surface is then smaller than the opaque body: or in other words, a shadow reflected from a dark body is always larger than the body, when the surface of the body furnishing the light is smaller than the surface of the body reflecting the shadow.

WHY, then, are the long evening shadows reflected by the sun from objects occasioned, as that a low wall should shadow a whole field, the shadow of the human or animal figure appear

many times larger than the figure, or that of a slightly projecting roof or a verandah should cover the whole front of a house?—BECAUSE the surface of those bodies is not directly to the light of the sun.

WHY do all objects, as steeples, towers, poles, &c., appear darker in their higher parts, and are so represented in drawings and engravings?—BECAUSE when the eye is directed to those objects, a great part of the retina of the eye is opposed to the light of the sky, and on moving the eye to look at the particular parts of the object, the reflected light from that object falls upon the retina, where it is exhausted by the direct light from the sky.

WHY is not the motion of light of a candle, or the interval of time which it takes to move from the candle to the surrounding objects in the room, perceptible?—BECAUSE of the great rapidity with which light travels, namely, 192,000 miles in a second.

WHY when a candle is extinguished does instantaneous darkness ensue?—BECAUSE the walls of the room and the surrounding objects absorb the rays.

WHY when a light is suspended by a long cord, and made to turn on it as on an axis, do two persons viewing it from the same point, or the same person at different times, suppose it turning different ways, sometimes to the right, and at others to the left, and vice versâ?—BECAUSE, on account of the extreme edges of light forming a circle, the spectator refers the motion of the light to the diameter which passes through his eye. If, therefore, one person takes the most distant extremity of the diameter for the nearer, while the other forms a correct estimate in this respect, the one will see the candle turning to the left, and the other to the right. For the same reason, the same

person may, at different times, and even without removing his eye from the candle, be subject to the like deception. The same deception also takes place in viewing in a very oblique manner the sails of a windmill in motion.

WHY, in aiming with a gun or an arrow at a mark, does the marksman close one eye?—FOR the purpose of taking a surer and more certain aim by the exclusion of all the rays of light except those that proceed from the point to which the attention is directed; and this is accomplished by directing the projectile along the straight rays of light which proceed from that point to the organ of vision.

WHY cannot sure aim be taken with a stone in a sling?—BECAUSE the point from which the stone to hit the mark should depart, cannot be determined.

WHY are passengers seen indistinctly by persons from the windows of a lighted room, while the passengers see the persons in the room distinctly?—BECAUSE the glass of the window acts as a reflector, and, therefore, throws back the rays of light passing from the lights in the room, so that the outside is in apparent darkness to those within the room, and therefore from the inability of the eye to discern objects in the dark, passengers are invisible to those within the room. The reason that passengers are seen indistinctly by persons from the window of a lighted room, while the passengers see the persons in the room distinctly, is, that the pupil of the eye, when passing from illuminated to dark places, becomes contracted, and therefore unable to exert the visual power for a certain time, whereas the pupil of the eye of the passengers is expanded, as they exercise their vision in a dark atmosphere.

WHY do bodies when viewed through the panes of glass of a window sometimes appear to be distorted?—BECAUSE the

two sides of the panes are not perfectly parallel to each other.

WHY do the distortions sometimes appear numerous and grotesque?—BECAUSE the obliquities of the surface of the panes are very various.

WHY are not objects distinguishable through glass which has been ground on the surface?—BECAUSE of the universal and minute refraction that has been produced in the glass by the multiplicity of minute surfaces occasioned by the grinding, and the consequent confusion that has been introduced among the rays of light, so that the spectra or images of objects are rendered too diminutive to be visible. As this method of preparation of glass has the effect of giving a greater diffusion of light, circular screens of ground glass are added to table-lamps.

WHY do objects viewed through a pane of glass appear to be multiplied as many times as there are obliquities in the glass?—BECAUSE the obliquities on the surface of one side of a piece of glass being distinct from each other, afford a separate or distinct view of an object placed on the other side of the glass. The views of the object are as many times multiplied as there are separate and distinct obliquities in the glass.

WHAT occasions the sky to appear blue or of an azure tint?—THE action of the rays of light upon the thin fluid of the upper stratum of the atmosphere, and that the violet and the indigo tints are reflected the most abundantly by the atmosphere. The bluish tints of distant mountains are occasioned by the same cause.

WHY does the sky gradually appear to lose its blue tint and appear of a dark or blackish hue on the heights of lofty mountains?—BECAUSE as the air diminishes in density in proportion

to its height above the level of the sea, it is too rare and its particles too few to receive and refract the sun's rays.

WHY does the sky appear within the regions where the simoom prevails of a yellow, violet, or dull blue colour?—BECAUSE the air is loaded with foreign substances, as minute pieces of quartz, blue coloured sand, &c. wafted from the districts from which the wind blows.

WHY can light be seen through glass, precious stones, &c.?—BECAUSE, by the extreme minuteness and velocity of its rays, it passes through the interstices between the particles of those bodies.

WHY, then, is not light seen as clearly through thick as thin glass?—BECAUSE the rays of light have greater difficulty to pass through thick than they have to pass through thin glass, being stopped in proportion to the thickness.

WHY can a white object be seen to a greater distance than an object of any other color; and why can it be seen when so dark that an object of any other color cannot be seen at all?—BECAUSE white color absorbs all the light which falls upon it, and consequently produces a stronger reflection than any other color can produce. It is for the same reason, namely, the reflecting of the light, that white garments are a cooler dress in summer and a warmer one in winter than black ones are, and that buildings whitewashed or covered with white plaster are the coolest kind of residences in summer.

WHY do microscopes and telescopes increase the bulk of objects?—BECAUSE they refract the rays of light that come from them so that they form a large angle with the eye, and therefore appear larger; all objects appearing large or small in proportion to the angle which lines or rays of light drawn or falling from them make with the eye.

WHY do mirrors that are not coated on the back afford but very indistinct images of objects viewed through them?—BECAUSE the glass transmitting the light to a considerable extent through it, reflects or throws it back but very faintly and indistinctly.

WHY does a straight rod or stick, when immersed in water, appear to be broken at the surface of the water, and the portion of it that is immersed in the water appear to be bent upwards? —BECAUSE the rays of light in their passage through a rarer to a denser medium, that is, from the air into the water, are infracted out of the straight line (which is the property of motion belonging to a ray of light when not refracted and reflected) into a bent or broken line or course. It is by the same cause also—namely, that objects viewed through transparent mediums are distorted or displaced—that an object seen through a prism or wedge seems to be thrown aside from its true place; and it is for the same reason that a deep bodied fish seen near the surface of the water seems to be flat; that a round body appears to be oval; that a shilling or other object placed at the bottom of a basin gently filled with water, or the painted flower which is usually at the bottom of cups, gradually appears to rise, and at last is seen at the top by a person placed at a short distance from the basin; and that objects seen at the bottom of the water do not seem at so great a depth as they really are; which last mentioned optical illusion has occasioned the death of many persons, it having tempted them to go beyond their depth in the water, they having mistakenly supposed that the depth of the water was that of its apparent shallowness where the object was seen. It is also for the same reason, namely, the refractive power of the water, that we fail to reach the precise point aimed at when attempting to spear or shoot a fish,

or unless we have made allowance for the refractive power of the water, by directing the aim at a point apparently below the object or fish. The reason, that when aim is taken from a ship in motion at a bird flying westward, the shot must be fired a little westward in order to hit the bird, is, that allowance must be made for the motal inertia of the shot.

Obs. As the refractive power of transparent substances or media depends on their comparative density or rarity, the rays of light are more or less bent or turned aside from their straight or natural course, according as the media through which they pass is denser or rarer. Thus, if a shilling or other object be laid at the bottom of a basin of water, and viewed obliquely, it will appear to be raised above the water; if instead of water spirits of wine be used, it will appear to be more raised; if oil, still more raised; and so in proportion to the density of the medium.

WHY does the change from a light or an illumined place to a darkened place occasion a temporary defect of vision so as to prevent objects in the dark place from being seen for some minutes?—BECAUSE the pupil of the eye requires time after it has entered the darkened medium to expand or dilate itself, in order to be enabled to take in a sufficient number of rays of light to enable the eye to exercise the office of vision.

WHY does the reflection of the sun's rays from the surface of water, or that of ice or snow, or from pavements, walls, buildings, or other objects, dazzle the sight, and excite a painful sensation in the eye?—BECAUSE the rays of the sun are reflected or turned back from the objects upon the eye.

WHY, in the change from a dark medium to a well lighted or an illumined place, and vice versâ, does the light cause a dazzling effect or a painful sensation in the eye?—BECAUSE

the pupil of the eye, in order to admit a sufficient quantity of the feeble rays of the dark place, has become too expanded to receive the impression of too many of the strong rays of light of a well lighted room; but as soon as the pupil is sufficiently contracted for the purpose, which it requires time to do, the painful sensation occasioned by the excess of light in the luminous medium ceases, and the power of vision is easily exercised.

*** Both the effects, namely, the temporary blindness and the dazzling light, are occasioned by the construction of the organ of vision, which is a natural optical instrument or camera obscura, as we imperceptibly contract or dilate the pupil of the eye in order to admit as many rays and no more than are necessary for distinct vision. Thus a person having been for some time in a great or a medium darkness has dilated the pupil of his eye to the utmost in order to admit the greatest possible quantity of rays of light; but if he suddenly goes into a strong light, the motion of the iris by which the required contraction is to be performed requiring time to adapt itself to the different degrees of light, too many of the intense rays of light enter, and thus cause the temporary dazzling effect to which he finds himself subject; as the contraction, however, becomes accomplished, his vision becomes proportionably distinct. The temporary blindness produced by the change from a light medium to a dark one is, where a person having been for some time in a bright light, the pupil of the eye has become contracted, and remains so for some time, having entered the dark medium; and the consequence is that a sufficient quantity of rays of light cannot immediately enter, and he feels himself for a short interval in a state of temporary blindness. The reason is the same when a person goes out into a dark place at night,

that he cannot see well until the pupil of the eye enlarges itself sufficiently according to the degree of light. To a prisoner after long confinement in a dark dungeon, the light of the sun is at first almost insupportable; but in a dungeon, which to common eyes is utterly dark, its long withheld inmate can see sufficiently well.

WHY does the dark of a total eclipse appear deeper after bright sunshine than that of midnight?—BECAUSE of the sudden change.

WHY, in pits and mines at the depth of sixty or seventy fathoms underground, is it quite dark in a clear sun-shiny day, whereas in a cloudy or rainy day it is sufficiently light to read at nearly twice that depth?—BECAUSE, when the atmosphere is full of clouds, light is reflected from them into the pit or mine in all directions, and thereby a considerable portion of the rays of light is reflected upon the earth; whereas when the atmosphere is clear, there are no opaque bodies to reflect the light in that manner, at least in a sufficient quantity, particularly in countries lying in such latitudes that the sun's rays can never fall perpendicularly on such countries. It is for this last mentioned reason that the phenomena above mentioned are of so frequent occurrence in the silver mines of Sweden.

WHY, when looking by daylight at the end of a needle stuck in a card and placed near the eye of the observer, does the needle appear to be behind the card, and reversed?—THE reason that the needle cannot be seen on the eye-side of the card is that the card is not at a sufficient distance from the eye; and that why the needle is seen reversed is that the rays of light crossing one another in the aperture cause the inversion of the image. The cause is the same, that images of surrounding objects are seen in a reversed position when viewed through a

small aperture made in a dark chamber, or through the medium of a camera obscura.

WHY does a gold fish in a glass globe appear in certain positions as two fishes?—BECAUSE the fish is then seen by rays of light bent and reflected through the upper surface of the water, as well as by straight rays passing through the side of the glass.

WHY are the spectra or images of objects seen by light admitted through a small opening always seen in a reversed position to that in which they really are?—BECAUSE of the obliquity or divergence of the rays of light, which, in passing through the opening, cross each other.

WHY do concave mirrors make objects appear longer, and convex mirrors smaller, than the objects are by which they are produced?—THE reason that convex mirrors form images of a diminished size is, that the reflected rays of light which produce them become divergent in their passage to the eye of the beholder, whereas concave mirrors, making them convergent, magnify them. It is for this reason that the image of a person looking into the eye of another is so very small.

WHY do convex mirrors and hollow spheres of glass covered on their inferior superficies with an amalgam similar to that used for silvering looking-glass, present panoramic pictures of surrounding objects?—BECAUSE the effect of light reflected from a convex mirror or hollow sphere produces a miniature picture of the objects placed opposite to it. It is for this reason that the globular bottles filled with colored liquids in the windows of chemists' shops, exhibit the moving scenery of the streets, the upper hemisphere of each bottle exhibiting all the images inverted, while the lower displays a duplicate of them in an erect position.

WHY do objects appear indistinct in the dark, and why is the indistinctness of their being seen in proportion to their remoteness, so as at length to become invisible?—THE principal impediment to the distinct vision of objects, whether remote or near, is deficiency of light and magnitude. Their gradual indistinctness is occasioned by the rays of light diverging from them passing through the dense medium of the air, a prodigious quantity of them being dissipated on the interval which intervenes between remote objects and the eye of the spectator.

WHY do objects appear more distinct, and their colors more vivid, according as they are nearer to the eye of the spectator?—BECAUSE the distinctness of appearance and the vividness of coloring depend on the intensity of light, which decreases in proportion to the distance of objects, in consequence of the interposition of the air comprised between the object and the eye.

How are those ludicrous caricatures of the human figure, and those of animals, produced in convex reflecting surfaces, as mirrors, &c.?—BY the variable curvature of the surface. That part of the surface which is most protuberant will exhibit a comparatively diminished image; and if the head and trunk be thrown backwards while standing near the mirror, the image will display a diminutive head and body, supported by preposterously swelled and gouty legs; but if, on receding from the mirror, the body be bent and the head stretched out towards the mirror, a monstrously bloated figure with a dropsical head and a body perched on spindle shanks will be displayed.

WHY is the intensity of artificial light, as that of a candle or a fire, diminished in proportion as the distance increases, and increased as it is diminished?—BECAUSE of the divergence and consequent dispersion of the radiant pencil of light, and vice versâ.

WHY do objects appear large or small according as they are viewed from near or far distances?—BECAUSE the number of rays of light emitted from the bodies, and which form the image of the object on the retina of the eye, increases or decreases as the squares of the distances of the object. It is for this reason that the size of a person is gradually increased or diminished in proportion as he approaches or recedes from a mirror or the hollow of the bowl of a polished metal spoon.

WHY do objects which are a little elevated and full in view appear in the evening or the darkness of the night far off, and much larger than they really are?—BECAUSE the darkness prevents the observer from judging of their distance by the quantity of the ground or the number of objects which intervene; we therefore refer the objects seen to the horizon, and consequently consider them proportionally remote and large. For it is a principle of optical science, that objects appear more remote and of greater magnitude in proportion as a greater number of objects are seen, and a greater extent of ground occurs between the eye of the spectator and those objects; while, on the other hand, they appear nearer and smaller as fewer objects are seen, and a less extent of ground occurs between them and the eye of the beholder. The cause is the same, that a valley is not perceptible which is posited in the middle of a plain, and that the objects which are beyond it appear very near to us, but recede to their actual remoteness when we approach to the edge of the valley.

WHY are objects sometimes seen more distinctly than at other times, and why do they appear of different dimensions at different times? — BECAUSE the air or medium through which they are seen influences their apparent magnitude.

WHAT causes the lateral radiations that seem to adhere to a candle when viewed with winking eyes?—THEY are produced by the reflection of light from the flattened edges of the lateral parts of the pupillary margin of the uvea.

WHAT occasions sparks to appear to be emitted when the eye is rubbed or compressed in the dark?—THE irritation produced on the retina.

WHAT occasions those lightning-flashes which are sometimes produced from the eye, from a sudden blow upon the head, or a blow or partial squeeze upon the eye?—THEY are probably produced on the nerves and muscles of the eye by the same cause as the impressions of lightning.

WHAT produces the circles of colors, like those in the feathers of a peacock's tail, that appear on pressing in a dark medium one corner of the eye with the finger?—THEY probably are produced by the same causes on the optic nerve, as vision is produced by the impulses of light on the bottom of the eye.

WHY does wine or any semi-transparent fluid appear in a champagne glass, or any other glass vessel of the same form, deeply colored in the broad part of the glass, but gradually become fainter in color as the glass tapers, until the color of the liquid almost disappears or becomes nearly as transparent as water?—FOR the same reason that sea-water or air when viewed in small quantities appears colorless.

WHAT occasions the various colors that light assumes?—REFRACTION, that is, that oblique direction or deviation from a straight line which its rays (namely, the various streams of particles of light) suffer in passing through the different densities of the atmosphere; being thereby bent or turned from their first course half a degree in the horizon.

WHAT is the color of light before it is decomposed by refraction into its prismatic colors?—WHITE.

How is that proved?—BY separating or decomposing its constituent parts, or the three primitive and different colored rays.

How is that effected?—BY means of a prism, a contrivance invented by Sir Isaac Newton, who, by admitting the light through a hole in a window shutter, found that each ray or pencil of light was of uniform whiteness; then intercepting that light with a prism, (namely, a triangular piece of glass,) he observed that the white ray of light in passing through the glass was so refracted or bent out of its course as to exhibit on the wall an image of seven different colors, namely, violet, indigo, blue, green, yellow, orange, and red. He then combined and gathered together those primary rays by the aid of a lens, and thus reproduced a white ray of light. And in corroboration of the truth of this experiment he mixed together one part of red lead, four parts of blue bice, and a due proportion of orpiment and verdigris; which mixture appeared of a dun color, like wood newly cut. He then took one-third of the mixture and scattered it over the floor of the room, in a place where the sun could shine upon it through the open casement; and at the side of the mixture, in the shadow, he laid a piece of white paper of the same size; then going to the distance of about twelve feet, so that he could not discern the unevenness of the powder or the little shadows let fall from its gritty particles, the powder appeared intensely white, so as to exceed the paper itself in whiteness.

*** Sir Isaac Newton's notion of seven primary colors is not correct, for Sir David Brewster has proved that there are but three primitive or primary rays in a sunbeam, namely, the

red, yellow, and blue, the four other colors mentioned by Sir Isaac Newton being compounded of those three. Thus, the intermixture of the red and yellow rays produces the orange-colored rays; the combination of the yellow and blue, the intermediate green; and the combination of the red with the blue, the indigo and the violet rays. The color resulting from a mixture of two primitive or elementary colors is an optical delusion; for though they are so blended as not to be capable of being separated by the naked sight, yet the two component colors remain perfectly distinct.

If, then, there are but three elementary or primary colored rays of light, how are all the varieties of the shade of color that are observable in nature produced?—Each of the elementary or primary colored rays has various degrees of refrangibility, according to the varying and unequal density of the medium of air through which it passes, and thus all the innumerable varied tints and combinations of colors with which nature is so profusely adorned, are produced. The variety of colors in which the creation is arrayed is not the result of any quality in the colored body, but arises from their property of reflecting or transmitting to the eye certain rays of white light, while they stop or stifle the remaining rays of which light is composed. The blushing beauties of the rose and the modest blue of the violet are not, as Goldsmith beautifully observes, in the flowers themselves, but in the light which adorns them.

What would have been the appearance of nature had there been but one color?—All would have been an impenetrable gloom. Had all the objects of the material world been illuminated with white light, all the particles of which possessed the same degree of refrangibility, and were equally acted on by

the bodies on which they fall, all nature would have shone with a leaden hue, and all the combination of external objects, and all the features of the human countenance, would have exhibited no other variety than that which they possess in a pencil sketch or a China-ink drawing. The rainbow itself would have dwindled into a narrow arch of white light,—the stars would have shone through a grey sky,—and the mantle of a wintry twilight would have replaced the golden vesture of the rising and the setting sun.

WHY, if color is not in bodies but in the light that surrounds them, do different colors appear in bodies?—BECAUSE the color of all bodies depends on their capacity of absorption, and the reflective and refractive power of the body. Thus, bodies that have a capacity of reflecting all the primitive colors without decomposing them will appear white, which is the assemblage of all colors; but if a body absorbs all the colors it will appear black, for black arises from an absence of light; consequently, if a body absorbs all the colors, but reflects red, it will be red; and if it absorbs all but green, it will be green; and so of the other colors. Thus is produced all the enchanting diversity of color in which nature decorates her productions. It is for this cause that grass and the leaves of trees and shrubs are green, because they reflect green. For the same cause the rose is red, the violet blue, the jonquil yellow, &c., &c. The appearance in bodies of one color by daylight and another by candle-light is occasioned by the mingling of the different rays emitted from the body, and of those produced by the artificial light. Thus, blue cloth appears green by candle-light, from the combinations or mingling of the rays of the cloth with the yellow rays proceeding from the light of the candle.

WHY, then, if candle-light occasions blue to appear green, do people of a yellow complexion appear by candle-light fairer than they really are?—BECAUSE the yellow cast of their complexion is not so visible, from the yellow tinge imparted by the candle-light to the surrounding objects.

WHY does a withered leaf appear yellow?—BECAUSE it has lost its tendency to reflect the blue rays, or it has a tendency to reflect several rays which produce its dingy brown color.

WHY, as the color of the air appears blue, does not the blue tint appear in air contained in a room or an empty glass vessel?—BECAUSE the intensity of the color depends on the proportion of the mass. This apparent anomaly is evident by inclosing a deep-colored liquid in tubes of different diameters, in which case the color of the liquid becomes gradually more faint in proportion to the decrease of their diameters.

How is it proved that light has the effect of representing colors?—BY noticing the glancing and varied hues on irregular surfaces of glass, ice, or other crystallized substances in which no color subsists.

How is that faint light called *morning* and *evening twilight*, which intervenes between the first dawn of morning and the rising of the sun, and again between the setting of the sun and the last remains of day, produced?—BY the refraction and reflection of the sun's rays from the upper regions of the atmosphere. The duration of twilight depends on the greater or less density of the atmosphere.

WHY do blue and yellow powders, when mixed, form a green powder to the sight, but when examined with a microscope, the blue and yellow grains appear separate and unaltered?—THE green hue is the mere effect arising in the eye from the intimate mixture of the ingredients.

WHY is the morning and evening twilight of use?—BECAUSE it prepares for the interchange of light and darkness, or the gradual transition from light to darkness, and *vice versâ*; otherwise in the morning we should pass instantly out of darkness into light; and light in the evening, when the sun sinks below the horizon, would suddenly disappear, and we should instantly be involved in darkness.

WHAT is the cause of the general blue color of the sea and the air?—THEIR disposition or capacity to reflect the blue constituent of the primary colors while they absorb the other constituent colors.

WHY has the sky a different aspect in every country?—BECAUSE of the different degrees of the rarefaction of the air, as also of the nature of the peculiar terrestrial exhalations.

WHAT occasions certain portions of the sea to partake of varied hues, different from its general blue color, as brown, yellow, red, green, milk-white, &c.?—THE admixture or presence of foreign substances, sometimes of a living or organic nature, and sometimes the reverse. Thus the waters of the Atlantic for the distance of three hundred miles from the mouths of the rivers La Plata and Amazon partake of a brown color, from the presence of the earthy particles brought down by these rivers. The Yellow Sea acquires its name from the intermixture of sand of a slightly yellowish tint; the Lake of Geneva partakes of a pale blue tint, from the vegetable substances by which it is impregnated; and the Red Sea, of a blood-red color from the algæ or marine vegetables which prevail in it. Thus also vast tracts of the waters of the Northern Seas partake of a green color from the presence of sea blubber, microscopic animalculæ, termed medusæ and infusoria. The color of the waters on the coasts of Chili, Brazil, Cape Horn, in

vast tracts of the northern and southern seas, the Bay of Loango, the Gulf of California, or, as it is otherwise called, the Vermilion Sea, which is of a blood or carmine red; the blood-red color of the pools in the steppes of Siberia, and which is sometimes observable in ponds and other pieces of water; the milk-white appearance of the sea near Cape Palmas, on the coast of Guinea, mentioned by Tuckey in his Maritime Geography, are also produced by the same cause, namely, the presence of infusory animalculæ. The varied color of seas also depends on the color of the materials constituting their bed or bottom.

WHY have bodies a tendency to absorb some rays of light and reflect others? — BECAUSE of the arrangement of their colors.

WHAT produces the phosphorescence of the sea, or those magnificent and splendid coruscations which appear in the undulations of its billows, and which surpass in brilliancy and effect the finest exhibition of fire-works?—THE presence and emission of splendid phosphorescent light emitted by the sea-animalculæ, termed the glow-worms of the sea; and possibly the friction of the saline particles of the water also contributes to the phenomenon. The petals of some flowers (as the nasturtium, the tuberose, and the African and common marygold) sometimes emit phosphorescent flashes of light on summer evenings in warm close weather.

WHY does ice appear at different times of various colors, namely, of a roseate hue, emerald green, sea-green, aqua-marine green, &c.?—BECAUSE of the refraction of light into all the colors of the prism from the innumerable cracks which are in the surfaces of the blocks.

WHY, when in an extensive plane terminated irregularly, do

we seem always to be in the centre of a large circle, and why do all elevated distant objects appear as though they were situated in the circumference?—BECAUSE the apparent figure of an object is determined by the situation of the points of that object which can send rays to it; and because that to the eye of a spectator, which is in the plane of any considerable line, such line appears as an arc of a circle whose centre is the eye itself. And the causes are the same, that a person when in such a plane does not seem to advance, although he is always moving; or that a remote sphere, as the sun or moon, appears only as a flat circle; or that a tower situated upon a polygonal base appears either round or flat, according to the distance; or that a revolving globe cannot, at a moderate distance, be perceived, unless there be one or more spots upon it, and that the globe revolves slowly.

WHY does a high tower or other upright building seem to lean forward?—BECAUSE the vertical line of the tower, and the vertical line which passes through the eye of the spectator, appearing to approach each other, occasion the tower or building to appear to lean or hang forward.

WHY does the sea seem to be more elevated in proportion as it recedes from the shore, and in proportion to the elevation of the spot from which it is observed?—BECAUSE the surface of the sea, which is horizontal, and the line of level which passes through the eye of the spectator, being both parallel, seem to approach as they recede from his eye; and the apparent approximation is the greater in proportion to the greater extent of sea subject to the vision. The causes are the same, that in a long gallery the floor appears to rise and the ceiling to be depressed in proportion to the distance of the spectator

from them; or that where a person is walking through a long avenue, or by a long wall, the parts that are to the right appear to bend more and more towards the left; or that when a person is between two rows of trees, they appear to separate from each other as he approaches them.

WHY are objects elevated above the usual surface of the earth, such as those which are situated on the summits of mountains, seen more distinctly than those that are situated at their base?—BECAUSE the air is rarer and more free from vapours on the elevations of the earth than that is which is on its surface.

WHAT occasions the tips of mountains, the surface of the ocean, and the clouds to be tinged with those vivid and beautiful colors with which they are seen invested in fine weather at sunrise and sunset?—THE reflection and refraction of the rays of light passing through a varying medium of the air. The different colors of the sky are attributable to the same cause, namely, to the different degrees of refrangibility possessed by each of the primary rays of light.

WHAT occasions the variation of color exhibited sometimes by the fixed stars, so that one twinkle or dilatation of the brightness of the star seems whitish, and the next or alternate twinkling red?—The alternate refractions of the atmosphere.

WHAT occasions the color of external objects, and particularly of natural scenery, to be greatly increased by viewing them with the head bent downwards, and looking backwards between the legs?—THE increased quantity of blood thrown into the vessels of the eye, an increased pressure being thus produced upon the retina, and therefore increased sensibility being given to the sentient membrane.

WHAT occasions the tremulous motion occasionally observable over chimney-pots and the slated roofs of houses heated by the sun's rays?—THE rising of the warm air, and its refractive power being less than that of the superincumbent air. Similar appearances occasionally take place from the same cause above the foot-lights of the stages of theatres, and above the flame of candles or the smoke of lamps.

WHY does the sky appear less distant in the zenith, that is, over our heads, than nearer the horizon?—BECAUSE the rays of light have to pass through a less quantity of the atmosphere. This is partly the reason that the sun and moon appear larger in rising and setting than when high in the zenith.

WHY does the horizon appear continuous to the sky?—BECAUSE we see nothing between the one and the other.

WHAT occasions the horizon to appear bounded by a line lower than that from which the vision is made?—THE curvature of the earth.

WHY, then, does the horizon when viewed from eminences appear more raised or elevated than when the dip or depression of the horizontal line is seen from inferior levels?—IT is occasioned by atmospheric refraction. It is to this cause that the appearance of the horizon is to be assigned when viewed from the top of the Peak of Teneriffe, namely, as Basil Hall describes it in his "Stray Chapters from My Journals," as if the person was "placed in the centre of a great bowl, the brim of which, at the distance of 140 miles, seems to be turned up some thousands of feet." The explanation of the fallacy of this apparent elevation is thus given by that distinguished navigator. "The angle subtended at the eye, by the space between the horizon of the sea and the nadir or point directly

under our feet, though, in strictness, it be the same, or nearly the same, as that between the horizon and the zenith, appears to the senses, under ordinary circumstances, to be much smaller. But when we ascend to great elevations, the immense distance to which the bounding line of our view is carried off, has the natural effect of appearing greatly to augment the angle between our nadir and the horizon. Consequently, the first impulse of the senses is to ascribe this change of appearance to the cause most familiar to us, that is, to an actual elevation of the horizontal line, as in the case of mountain scenery viewed from a distance."

WHY does the sky appear to us as a depressed concavity, and not a concave hemisphere?—BECAUSE the light of the stars being less vivid as they are nearer the horizon, those stars which are the most elevated appear less remote, and *vice versâ*. The apparent depression of the upper parts of the sky explains the cause why the stars appear so much larger when near the horizon than in other positions, and seem to diminish when they rise above it.

WHY does the sun appear red at rising and setting, or when seen through a fog?—THIS problem is not philosophically solvable; but probably the density and increased quantity of the atmosphere which the rays of the sun must traverse, gives a greater momentum to the red rays, and thus diminishes the power of the other rays.

WHY does a burning coal or an ignited stick, or other light, when turned rapidly round, appear as a ring or circle of fire? —BECAUSE the impression of the light on the retina produces certain vibrations or impressions of light, which during the sensation of the luminous particles remain entire on the eye

till they are renewed by the arrival of the coal at the same point again; for visible sensations have a sensible duration; consequently, if the burning coal, &c. be made to perform its revolution before each vibration caused by the first impression ceases, the result is, the sensation and appearance of the ring or circle of fire.

WHY does moistened paper appear more transparent than paper in its dry state?—BECAUSE the liquid penetrates the pores, which in a dry state are clogged with fine interwoven threads, and consequently it breaks the connection of those threads, and the pores become so many small tubes filled with liquid adapted to transmit light, and give to the paper the transparency, by allowing the light to pervade it.

WHAT occasions spectral illusions, or the illusory perceptions of objects to which the vision of some persons is subject, or which in common parlance are called apparitions, spectres, or ghosts? — ORGANIC or functional disease of the brain and nervous system; morbidity of imagination, peculiar temperament of body, and, according to phrenologists, a particular developement of that portion of the brain which they denominate the seat or organ of wonder. The seers of visions, the dreamers of dreams, and the workers of miracles are among the most inveterate professors of these illusions.

WHAT occasions the aërial spectra or optical illusory appearances of objects pictorially raised or elevated vertically in the atmosphere, and sometimes multiplied, distorted, inverted, and increased to an extraordinary size to the vision of the beholder? —THE refractive power of the atmosphere under peculiar circumstances of temperature, as its variation and unequal density. By means of that power distant terrestrial objects are elevated to the view, when the spherical curvature of the earth

causes their concealment. These phenomena receive different names in different countries. By the French they are termed "the mirage or spectral lake;" by the Italians, "the Fata Morgana" (or the fairy illusion); by the Germans, "the Bogle or Brocken," (that is, the colossal figure); by the Arabs and the Persians, "the siraub, or the vater of the desert;" and in our own language they have the vague and general term of aërial spectra, or optical illusory appearances. For the various occurrences of these phenomena, the causes of their production, and their rationale or *modus operandi*, see *Terrestrial Mechanism, or the Wonders of Geology Displayed.*

ASTRONOMY.

ASTRONOMY (compounded of the two Greek words *aster* or *asteron*, a star, and *nomos*, a rule or law) is the science which teaches the knowledge of the heavenly bodies; namely, their structure, magnitudes, order, offices, motions, periods, eclipses, and other properties, together with the laws of their relative dependence, and which regulate their government and economy.

"Astronomy is the sublimest and the most instructive subject with which the mind of man can be acquainted:—*Sublime*, as it not only reveals to us the origin and wonderful mechanism of the universe, displays its scenery and unfolds the laws and causes by which it is upheld and preserved; but it introduces us, as it were, to the sanctuary and counsels of its Divine Creator, with whom we may be said to hold, in

stillness and silence, converse and communion in his creations and designs:—*Instructive*, as it opens to us the most varied and overflowing sources of moral and intellectual employment and delight with which the illimitable expanse of Nature abounds, and which have been given to man for the best and wisest and most exalted purposes, to enable him to trace and discover in

'This gorgeous apparatus,
This demonstration of creative power,'

the might and majesty of the Great First Cause and Giver of Good, and to reverence and adore him

'In his word, his works, his ways.'

"Throughout the whole and entire system of Nature, from the mightiest to the minutest of her works and wonders—from the magnificent spectacle of the expansive dome of the heavens studded and bespangled with countless millions of brilliant orbs, careering through the illimitable regions of space in the most perfect order and harmony, to even the vilest weed that grows upon the earth, and the meanest insect that crawls upon its surface,*—abundant and incontestible proofs are afforded of the infinite wisdom and almighty power of their Creator; but

* "The structure of a fly, or of a single blade of grass, is as elaborate and perfect as that of the stateliest productions of the forest, or of that perfect piece of mechanism—man, godlike and intellectual, breathing the divine spirit and panting with immortal aspirations. From the first link to the last in the chain of creation, from the archangel down to the lowest reptile that crawls in the dust, every single creature or atom, according to its nature and capacity, throughout the vast regions of created matter—in a word, every thing that peoples the earth, the ocean, and the air—every stupendous and magnificent, as well as every minute and insignificant

none presents more powerful and convincing evidences of the pervading energies and the superintending providence of a Supreme Creative Spirit, and calls forth so much admiration and astonishment, so much awe and veneration, as the simply and sublimely beautiful mechanism of the Celestial System, or the Wonders of the Heavens, consisting of myriads of spherical bodies, composed of gaseous or solid materials, from that of diffuse luminous vapour to opaque solid bodies like our earth—all regulated and maintained by sublime and unerring laws, from which they cannot deviate.

> 'Lightnings and storms his mighty will obey,
> And planets roll where he has marked the way;'
>
> 'He gives and guides the sun's impulsive course;
> With hand unseen directs the general cause
> By firm immutable immortal laws!"
> *Celestial Mechanism; or the Wonders of the Heavens Displayed.*

How is the science of Astronomy divided for its easier comprehension?—INTO the Celestial, the Solar or Planetary, the Stellar or Sidereal, and the Cometary Systems.

WHAT bodies are comprehended in the term the Celestial System?—THE whole of the bodies which constitute the celestial world, namely, the Sun, the Planets, the Stars

object that is scattered over the face of Nature—affords the most beautiful and convincing demonstrations of creative foresight and design, declares the wisdom, and

> 'With a thousand voices calls on God,'

proclaiming the power of a Supreme and Omnipotent Intelligence."
—*Celestial Mechanism; or the Wonders of the Heavens Displayed.*

(both stationary and wandering), the Constellations, and the Comets; and even our Earth, or the terrestrial world, is comprehended within the term.

WHAT are included in the term the Solar System?—THE Sun, and the Planets with their satellites; namely, Mercury, Venus, the Earth, the Moon, Mars; Vesta, Juno, Pallas, Ceres; Jupiter, Saturn, Uranus, (or as it is sometimes called, Herschell, or the Georgium Sidus,) and Neptune; all of which revolve, in the numerical order mentioned, round the sun as their common centre. The term "the Planetary System" includes only the Planets and their Satellites.

WHAT does the term "the Stellar" or "Sidereal System" include?—THE Stars, both fixed and wandering.

WHAT "the Cometary System?"—THE Comets.

WHAT is the form or shape of the celestial bodies?—SPHERICAL, or, more correctly speaking, spheroidical, that is, flattened at their poles and jutting out at their equators. The earth is of the same form.

How have they obtained that form, and how do they still retain it?—BY the reciprocal attraction of their component particles towards one another, that is, towards a common centre, as also by their rotatory motion. Interesting instances of this great and inherent property of matter, and on which the conservation of all created matter depends, occur in very minute masses and constantly before our eyes: dew-drops trickling from the leaves and flowers of plants and the duck's wing,—the tears dropping from the cheek—the particles of vapour floating in the air, and there coalescing, forming drops of rain—globules of mercury coalescing when near, and forming larger globules—melted lead falling through a sieve from a great height into water and there forming shot perfectly spherical—

with a multitude of other instances confirmatory of the great and primary conservative principle or law of Nature.

WHY is the spherical or globular form of greater advantage than any other form? BECAUSE of the greater attractive power of its component particles in their galvanic attraction to a common centre.

WHAT is the form of their movements or revolutions?—ELLIPTICAL or curvilinear.

WHY do the celestial bodies as also our earth pursue elliptical or curvilinear paths; how is that ellipticity or curvilinear path produced; and how are they preserved in that course of revolution?—THEY pursue elliptical or curvilinear paths, because of the joint influence of the centrifugal and centripetal (or the centre-fleeing and centre-seeking) forces, the ellipticity being produced by the inequality of those forces; and they are impelled into a state of motion, because bodies have, from their property of inertia, a tendency to proceed in a straight line of direction for ever, but that principle of direct motion, which in the language of science is termed their *centrifugal force* or *law of motion*, is counteracted or deflected by the centripetal force or the law of attraction or gravitation, a principle inherent in nature, and of equal force and power in all bodies, however large or small; or in other words, the ellipticity or curvilinear path of the planetary and all other motive bodies, and their preservation and continuance in that course of revolution, are occasioned by the horizontal or straight-onward direction produced by the impressed or projectile impulse of the centrifugal force or law of motion, and the elliptical or curvilinear direction which they assume from the straight line of motion first imparted to them is produced by the centripetal force or the law of attraction or gravity; but

these two joint and counteracting forces not being equal in their velocity, the horizontal direction being uniform, but the descending motion produced by gravity or attraction being in an elliptical direction; consequently, by the balance of those two forces, the onward tendency and the attractive tendency produced by the centrifugal and the centripetal forces, or the counteracting influences of the laws of motion and attraction, the planetary bodies assumed elliptical paths or orbits; and by the same laws and influences they continue to pursue such paths or orbits, being propelled forward by one force or law, and withheld and constrained to assume an orbicular or a curvilinear path or orbit by the antagonist force or law, and the ellipticity is produced by the inequality of the influence or power of the counteracting laws or forces.

WHAT is the meaning of centripetal and centrifugal forces? THE centrifugal or centre-fleeing force is the tendency of a body to fly off in a tangent or straight line from motion round another body as its centre of action; as of the earth in its revolution round the sun. The centripetal or centre-seeking force is the power which prevents bodies from flying off from a centre, and draws them to it. These two forces, which are among the great primary laws of Nature, are exemplified in a thousand instances in the common occurrences of life: thus in the case of persons or animals rapidly turning the corners of streets —the position assumed by persons skating on circular and curvilinear paths—persons performing equestrian feats in the circus of theatres,—or the action of turning a circular grindstone with water in contact with it, when the particles composing the rim of water on the stone, though they preserve momentarily the straight line, yet, in falling, assume the curvilinear or bent direction.

WHY is the rotatory motion of the celestial bodies, and of the earth, on their axes, necessary? — FOR upholding the various systems of which the celestial bodies and the earth consist. Thus, in the case of the planetary system, if that motion ceased, the sun's central attraction would be so great that the other bodies of the system would be drawn into contact with him.

WHAT is the meaning of the expression *attraction* or adhesive attraction?—A FORCE or principle inherent in Nature, by which every atom or particle of matter has a tendency to approach or to be attracted towards another particle or atom.

WHAT that of gravitation?—THE property or principle inherent in all matter, whether of the size of a globule or a globe as large as or larger than our earth, which bodies and every atom or particle of matter have to gravitate or be attracted to a centre.

WHAT are the preservative powers of the heavenly orbs, the earth, and all the objects of nature?—THE centrifugal and the centripetal forces, or the repellant and the attractive powers, the first called into action by heat, the second by attraction or gravitation.

WHY is not the motion and great velocity of the planetary bodies perceptible to the inhabitants of the earth?—BECAUSE of their immense distance, the angle under which their motion appears to the eye being too small to be visible.

WHY, then, are the fixed stars, which subtend much smaller angles than the planetary bodies, perceptible?—BECAUSE, being luminous bodies, their extraordinary degree of illumination renders them visible.

How is it proved that the planets revolve round the sun?—BECAUSE as the sun and the planets mutually attract each other, and as they are in equilibrio by this attraction, their mo-

menta or forces must be equal; and as the centre of gravity between any two bodies must be as much nearer to the centre of the larger body than to that of the smaller, as the quantity of matter of the former exceeds that of the latter, the smaller, being compelled to compensate by its motion its deficiency in matter, must revolve round the larger. To suppose that the sun moves round the earth is as absurd as to suppose that a mill-stone could be made to move round a pebble.

WHY do the heavenly bodies appear to assume the position of rising and setting?—BECAUSE of the rotatory motion of the earth on its axis during every twenty-four hours. Thus, as the earth revolves on its axis from west to east, the optical illusions of the rising and the setting of the sun and of the other heavenly bodies are occasioned by the earth continually, as it were, falling below the heavenly bodies on the eastern, and rising above them on the western horizon, and therefore those bodies come into sight as the eastern edge of the earth's horizon falls below them, and are hid from view as its western edge rises above them.

WHY is the sun of use, and what is its office in the solar or planetary system?—BESIDES being the general centre about which the planets revolve, it furnishes light and heat, occasions the alternations of the seasons and of day and night, and produces a distribution of water over the earth, by raising the vapours off the sea and the surface of the land.

WHAT is the size of the sun?—ABOVE a million times greater than that of the earth.

WHAT is the distance of the sun from the earth?—ABOUT ninety-five millions of miles.

How has the rotation of the sun on its axis been ascertained?—BY the appearance of dark spots or maculæ, which

are interspersed over its disk or surface. Rotatory motion of the other heavenly bodies has been ascertained by the same means.

WHAT do the maculæ or spots which are interspersed over the disk or surface of the sun, and which to the naked eye appear like the form of a face, indicate?—THE existence of mountains on his surface; they being merely the elevated parts. The similar appearances of the moon, as observed through the telescope, indicate its mountains, and the darker spots its valleys.

WHY do we see the sun (a phenomenon which also occurs in the case of the other heavenly luminaries) a few minutes before he has actually risen, and retain a view of his disk after he has sunk below the horizon?—BECAUSE the rays of the sun on reaching the confines of the atmospheric fluid which envelopes the earth, entering a medium of greater density than that which they have been previously pursuing, are refracted or turned from their first course in an oblique direction in the density of the atmosphere half of a degree in the horizon; and therefore they reach the eye sooner than if there had been no refraction; consequently, the phenomenon of the sun's appearance is produced before he has risen above the horizon. In the same proportion as the refraction diminishes as the sun approaches the zenith, it increases as it recedes towards setting; and thus we are enabled to retain a view of its disk after it has sunk below the horizon. The same phenomena are the causes of the similar appearances of the other heavenly bodies.

WHY do we never see the sun in the actual position which it occupies?—BECAUSE of the reason just stated.

WHAT is heat?—A quality or affection of matter pervading